

**NORTH CAROLINA OUTER BANKS BEACH NOURISHMENT
SAND RESOURCE STUDY, FIRST INTERIM REPORT:
SHALLOW, HIGH-RESOLUTION SEISMIC
SURVEY, OFFSHORE NAGS HEAD AREA**

by

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**NORTH CAROLINA GEOLOGICAL SURVEY
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Jonathan B. Howes, Secretary

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SUMMARY

This report presents the initial results of a reconnaissance survey focused on identification of potentially suitable sand resources for beach nourishment along the North Carolina Outer Banks. Approximately 300 kilometers of high-resolution seismic-reflection profile data were collected along 15 separate tracklines offshore of Nags Head, North Carolina. These data have been interpreted, scale-rectified, and reduced to seismic stratigraphic sections. The seismic sections present a window to the shallow, subbottom geology. They depict several large shoals overlying a stacked series of tabular stratigraphic units. Each stratigraphic unit is 6 to 20 meters thick and all are bound by unconformity surfaces cut by multiple, relict (buried) stream valleys. The shoal features exhibit 3 to 15 meters of topographic relief, are common at water depths greater than 20 meters, and appear to be erosional in origin.

An unusually thick bottom signal has masked the very shallow subbottom section (<5m), particularly in the shoal areas. This signal is either inherent to the surface geology (seafloor character), or a by-product of boat-noise from the vessel employed to collect the seismic data. Future surveys will utilize different research vessels and thereby provide a test regarding boat-noise artifacts.

Additional data are required to: (1) develop a detailed three-dimensional geological framework,

(2) integrate the existing data set with onshore or barrier island stratigraphies and thereby develop an internally consistent geographically-referenced data base, (3) map the infilled channel thalwegs which crop out on the sea-floor, and (4) identify specific vibracore targets within the survey area.

INTRODUCTION

The Outer Banks of North Carolina present a major tourist attraction which, in turn, has provided accelerating annual tax revenues — as well as significant population growth — over the past 2 decades (Table 1). The lure for this flourishing economic development is a magnificent stretch of barrier island beachfront. Yet, the health of this very same beachfront property has been given a very poor prognosis. It is threatened by the natural hazards of slow and persistent sea-level rise which continues to force coastal erosion and shoreline retreat. More specifically, nor'easter storm damage over the past 5 years has become more frequent, and coastal destruction resulting from these *non-hurricane* storm events has become more severe (e.g., the HalloWind Storm of 1991). Coastal destruction from storm-surge flooding and beachfront erosion will likely increase in frequency and magnitude as sea-level continues to rise. The socioeconomic consequences of each storm-surge event, coupled with the forecast of higher-frequency in storm events, have collectively raised the status of shoreline preservation (and maintenance of emergency-evacuation routes) to higher levels of concern for the State of North Carolina, as well as the local governments and agencies of the Outer Banks' communities.

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	Dare	Currituck	Total		Dare	Currituck	Total
Population (+161)				Seasonal Housing Units (+291 %)			
1970	6,995	6,976	13,971	1970	1,783	136	1,919
1980	13,377	11,089	24,466	1980	4,643	706	5,349
1990	22,746	13,736	36,482	1990	6,416	1,096	7,512
Hotels/Lodging Earnings (000's) (+675 %)				Ad Valorem Tax Revenues (+280 %)			
1970	N/A	N/A	N/A	1970	\$1,706	\$133	\$1,839
1980	\$2,641,369	\$1,822,753	\$4,464,122	1980	\$5,891	\$125	\$6,016
1990	\$10,456,215	\$6,503,846	\$16,960,061	1990	\$13,115	\$1,143	\$14,258

* Percent change is from earliest listed to most recent data

Table 1. Economic indicators for northern North Carolina Outer Banks (from LINC database, 1991).

A variety of erosion abatement practices have been attempted with minimal success along various segments of the coastline over the past 25 years (NRCD, 1984). After much debate, in 1984 the NC Outer Banks Beach Erosion Task Force produced recommendations regarding beach stabilization and erosion abatement practices. These recommendations were later incorporated into the North Carolina Administrative Code by the Coastal Resources Commission (Figure 1). The effect of these regulations is to establish beach nourishment as the preferred shoreline stabilization alternative. Still, the source(s) of beach-renourishment sand has not been identified for most of North Carolina's coastline, nor has any resource assessment program been established. The only previous sand-resource surveys have been completed under the Inner Continental Shelf Sediment and Structure (ICON) program administered through the U. S. Army Corps of Engineers Coastal Engineering Research Center. All ICON survey areas in North Carolina lie entirely south of Cape Lookout, and concentrate on shelf areas south of Topsail Island (Meisburger, 1979). North of Cape Lookout, the nearest area investigated during the ICON study is off the mouth of the Chesapeake Bay.

In order to facilitate rational cost/benefit evaluations for future beach-replenishment proposals along the Outer Banks, especially for those sectors forecasted as requiring remedial beach-erosion action within the next decade (Stone and others, 1991), detailed information delineating the location, texture, and volume of sand resources are required. This report represents the first step toward filling that information gap on offshore sand resources. Subbottom stratigraphic data from an area offshore of Nags Head are presented. These data are not dense enough to complete a detailed assessment of sand resources off Nags Head. Instead they provide an important data set which will initiate the process of constructing an internally consistent, three-dimensional geological framework. This framework will then serve as a blueprint for targeting core sites. Once the subbottom stratigraphy is coupled with core information, the identification and quantification of sand resources can be established.

DATA BASE

Approximately 300 km of high-resolution seismic-reflection data were collected along fifteen separate tracklines (Figure 2). The survey area lies between Oregon Inlet and Jockeys Ridge, and ex-

The 93 miles of shoreline from Cape Hatteras to the Virginia line average 4.7 feet of erosion per year (NRCD, 1984). Annual rates for selected segments of recently developed coastline commonly exceed 10 feet per year (McCullough, 1988). In July 1984, the Coastal Resources Commission's Outer Banks Erosion Task Force reported the results of a 6-month study which focused on erosion problems of Dare and Currituck Counties. They concluded with a series of policy recommendations for statewide applicability, many of which were accepted by the Coastal Resources Commission and incorporated into the North Carolina Administrative Code (*NCAC Ch15A, SC 7H, Sec. .0003*) under its rule making authority. The Task Force recommendations most pertinent to this proposal which were made part of the N.C. Administrative Code or adopted as official Commission policy are:

- Efforts to permanently stabilize the location of the shoreline by massive seawalls and similar protection devices which do not preserve public trust rights should not be allowed.
- Beach nourishment is the preferred response to erosion. Sand used for nourishment should be compatible with existing grain size and type and should be obtained from sources that minimize environmental damage.
- A systematic detailed survey of sources of suitable sand for beach nourishment should be done.
- All artificially accreted oceanfront lands, however financed, should be publicly owned.

Figure 1. A summary of North Carolina beach stabilization policy.

tends out from the base of the shoreface to about 16 nautical miles. The seismic lines were run parallel to proposed tracklines designed at a grid spacing of one nautical-mile. Weather and equipment failures prohibited completion of the entire grid of tracklines.

All data presented in this report were collected aboard a 36-foot charter boat captained by Mr. Charles Midgett of Wanchese, North Carolina. The seismic profiles are single-channel analog data. The seismic source (UNIBOOM™) emits a broad-band, high-frequency wave-spectrum (400 Hz to 14 kHz). The theoretical vertical resolution of this instrument is 20 cm; working vertical resolution was found to be slightly less than 1 meter. Pulse-generation was powered at 300 joules and triggered by a mercury-vapor ignatron. Firing rates varied, but never exceeded 0.5 seconds/trigger in order to maintain extremely-high horizontal resolution. Sweep rate was fixed at 100 milliseconds (2-way travel time), and therefore penetration was limited

to the first 90-100 meters (depending on the *in situ* subbottom seismic-velocity structure).

The incoming signal was collected on an eight-element hydrophone, amplified, filtered, and recorded on an analog graphical recorder. The data were also magnetically taped using a high-fidelity VCR. The taped data are used for post-cruise processing.

Navigation was determined using LORAN C time-differentials. Navigation positions were continuously logged at 1-minute intervals by employing a proprietary software program and a portable PC computer to capture and store this information. In addition, time-events were marked on the seismic profiles at 5 minute intervals (or less), and position information was simultaneously recorded for each time-event. This facilitated geo-referencing of the seismic data. Time differentials were converted to latitude/longitude coordinates using a NorthStar 800™ conversion program (Ver. 96).

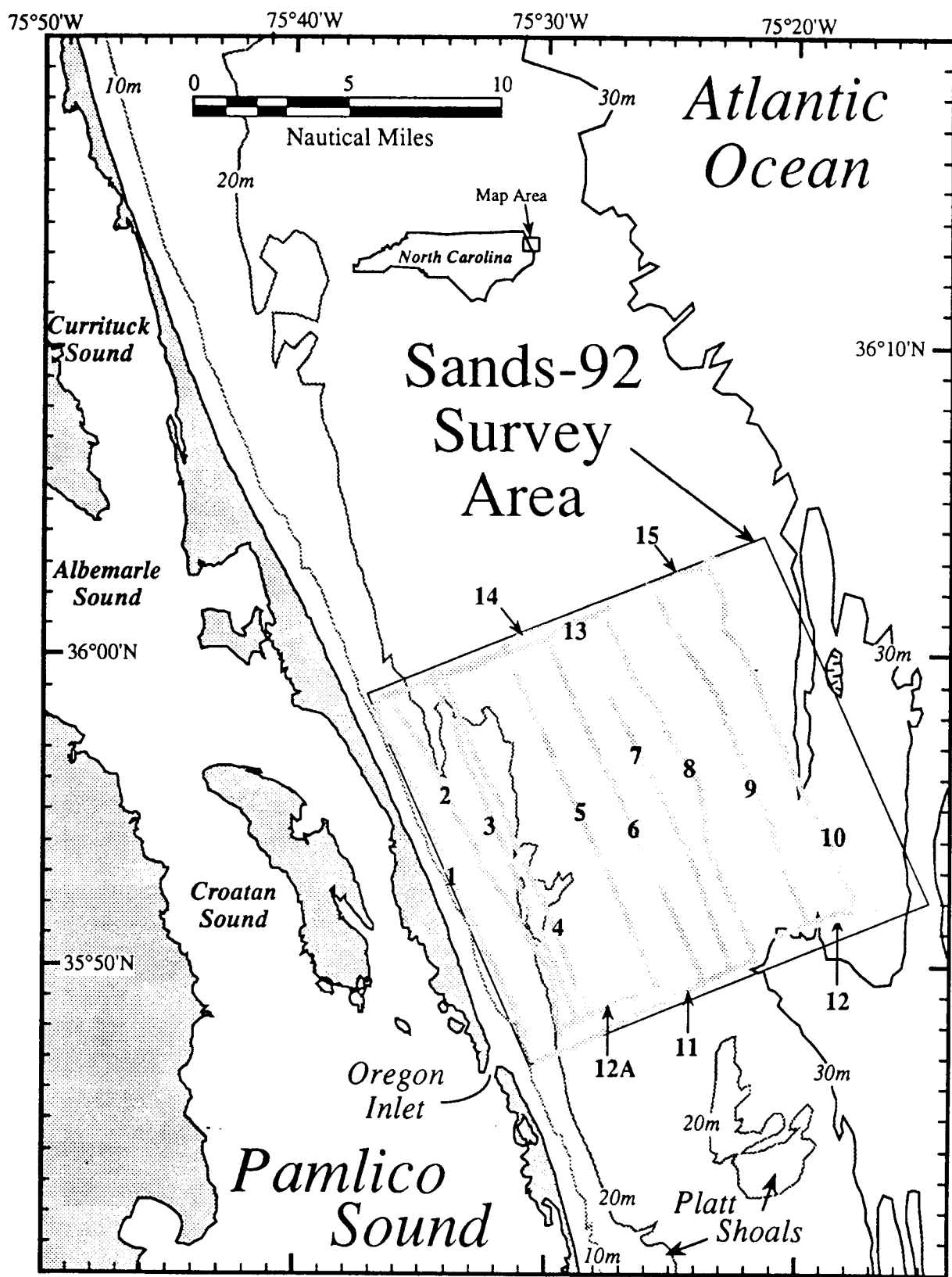


Figure 2. Base map delineating the 1992 Sands survey area and the location of seismic tracklines for profiles presented in this report. Numbers refer to individual seisections shown in Appendix A.

The latitude/longitude coordinate information was then plotted by hand on NOAA Coastal Chart # 12204, as well as entered and manipulated in computer mapping programs.

DATA REDUCTION

Only 271 km of the approximately 300 km seismic reflection data set were reduced to a series of seismic stratigraphic sections due to overlaps in tracklines or poor data quality. These seismic stratigraphic sections are presented in Appendix A, and are herein referred to as "seisections".

The method of translating the graphical seismic records to seisections is described in Snyder (1993). This method consists of 3 basic steps. First, the raw seismic data were photocopied, studied, and subbottom reflectors were interpreted to be either real reflecting horizons or a multiple of some type. Real reflectors were highlighted using a four-color scheme to subjectively portray the relative amplitude of the reflectors. Second, the interpreted photocopies were then systematically reduced to stratigraphic line-drawings by hand-digitizing each highlighted seismic reflector. The digitizing exercise utilizes a large-format (4 x 5 foot) digitizing tablet and microcomputer workstation. Proprietary software was used to rectify horizontal and vertical scaling. Digitized reflector information was stored in a 4-dimensional array (latitude, longitude, depth below sea-level in milliseconds, and reflector amplitude color code). Third, plots were then produced on a large-format drafting plotter at a pre-determined vertical exaggeration of 100:1. Color coding on these plots reflects relative amplitudes. In black and white illustrations, each color is assigned a different line weight.

Digitized seisection information was imported and manipulated through several Macintosh™ graphics programs, converted to stratigraphic line drawings, annotated, sized for publication, and then printed. Time-events corresponding to numbered navigation positions are shown at the bottom of each seisection and on the map view of the track

line. The position of the time-events are plotted in both the map views and seisections presented in Appendix A.

The vertical meter scale shown in all seismic profile data and seisection drawings is an *approximate* scale. It was calculated using a water-column seismic velocity of 1500 meters/second, and a second velocity of 1700 meters/second for subsurface travel-times (an approximately 13 percent increase). Seismic velocities recorded in unconsolidated to semi-consolidated, siliciclastic or carbonate, stratigraphic sections range from 1600-2300 meters/second (Sheridan and others, 1966; Grow and Markle, 1977; Buffler and others, 1979; 1981; Grow and others, 1979; Ebeniro and others, 1986; Slowey and others, 1989). More typically, the velocity range for unconsolidated siliciclastics is in the 1650-1750 meters/second range (Snyder, 1993).

RESULTS

The seismic data depict a series of tabular subbottom sequences abruptly interrupted by multiple paleofluvial channel systems (Figure 3). Each seismic sequence is bound by erosional unconformities which appear parallel to subparallel with the seafloor. The seismic sequences range from 5 to 15 meters in thickness, and the physical anatomy (seismic facies) indicate these tabular units represent a stacked mosaic of shelf, estuarine and fluvial lithologies. However, no core data are presently available for correlations, nor have seismic lines been carried to existing borehole information.

The subbottom seismic sequences are overlain by several distinct shoal features (Figure 4). These shoals exhibit the following specific characteristics: (1) they are near-ubiquitous at water depths greater than 20 meters; (2) they range from a few meters to over 15 meters in thickness, and the thickness appears to increase with increasing water depth; (3) all shoals exhibit microtopographic relief (± 2 meters) superimposed over the larger shoal-

Figure 3. Seissection S-92-06 illustrating the anatomy of the subbottom stratigraphy underlying the inner continental shelf area off Nags Head, North Carolina. Location of the seismic trackline is shown in Appendix A.

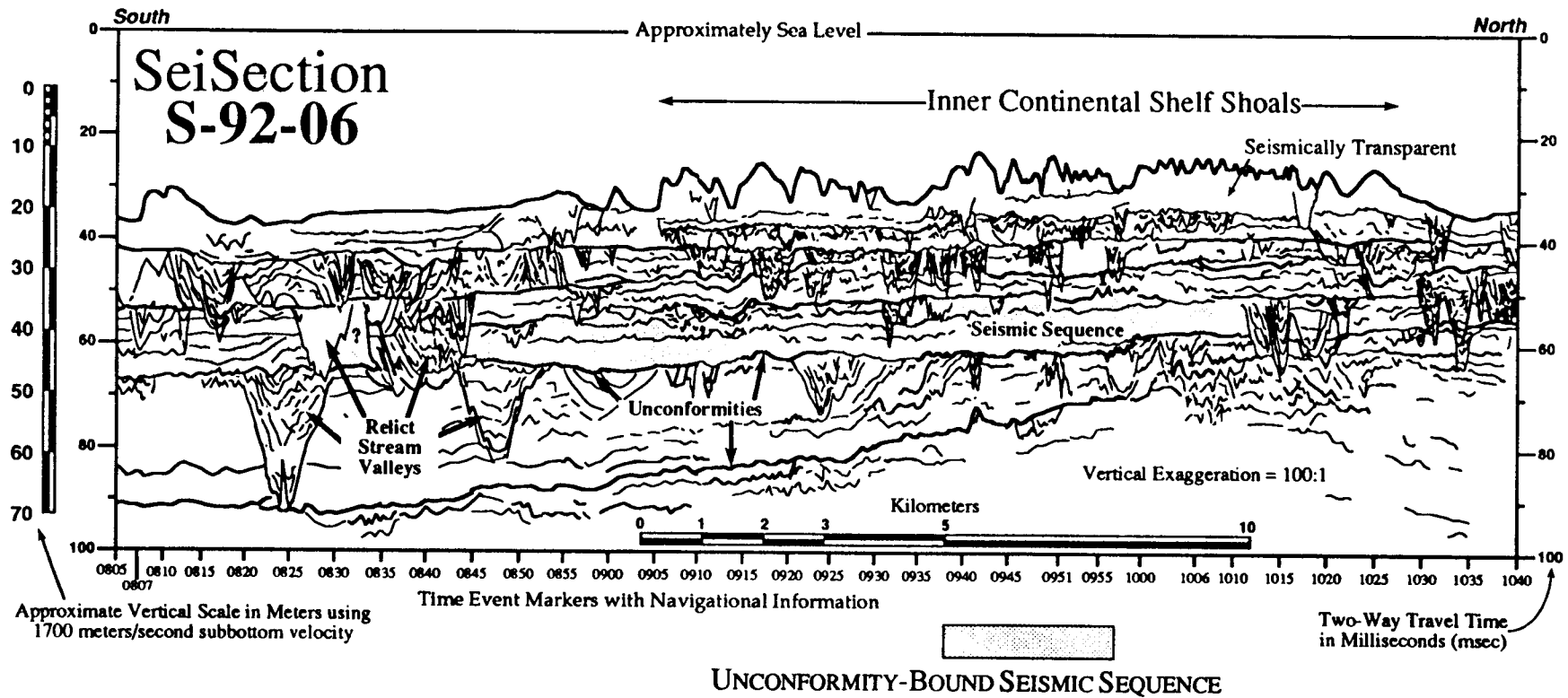


Figure 3. Seissection S-92-06 illustrating the anatomy of the subbottom stratigraphy underlying the inner continental shelf area off Nags Head, North Carolina. Location of the seismic trackline is shown in Appendix A.

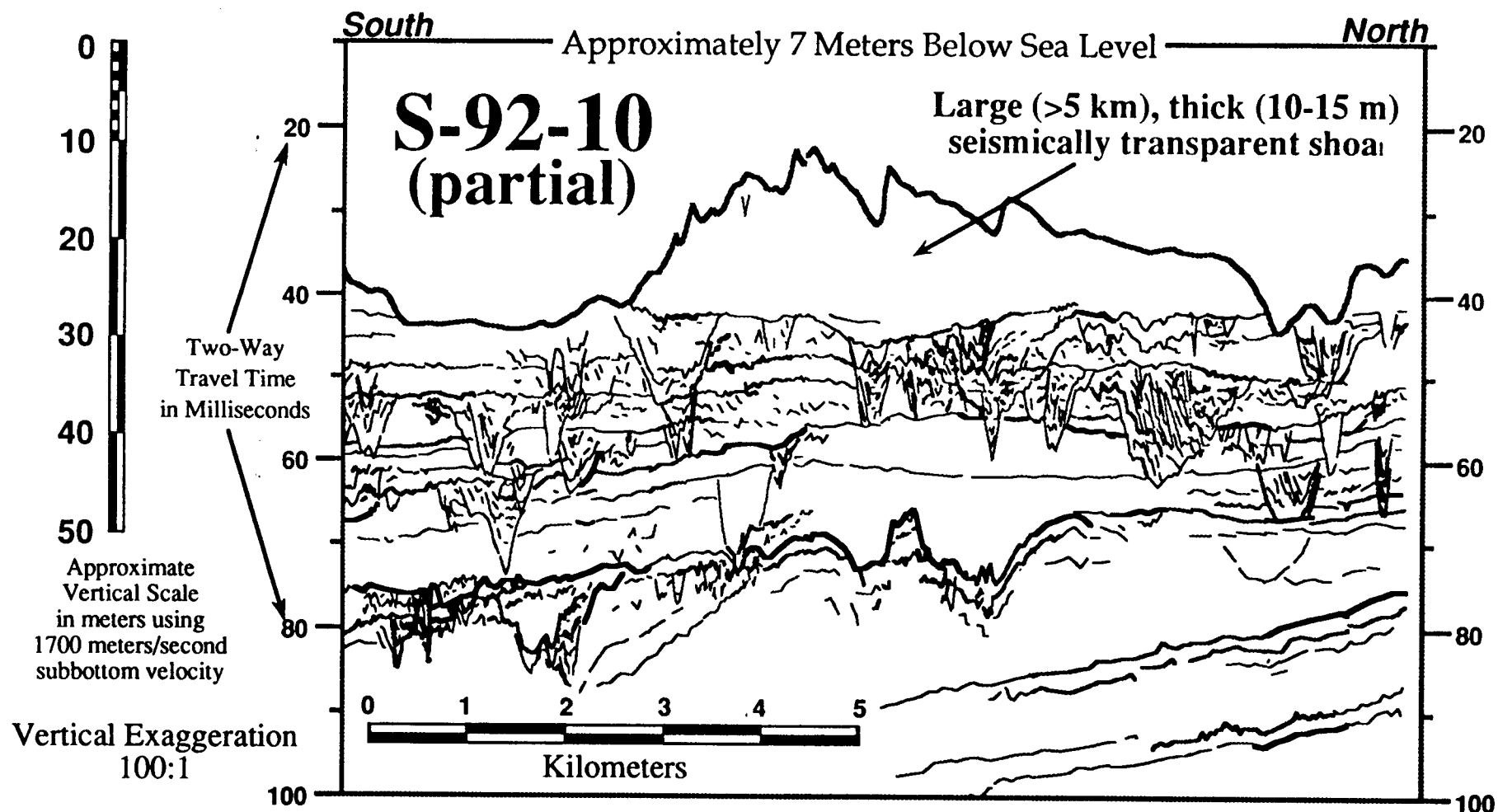


Figure 4. A segment of seisection S-92-10 which shows the size and shape of the larger shoal features identified at deeper water depths (>30 m) within the S-92 survey area. See seisection S-92-10 in Appendix A for reference to the location of this section.

feature (Figure 5); (4) most shoal features portray a transparent seismic facies (Figure 4); and (5) the seafloor seismic signature from all shoal areas is marked by an anomalously thick reflector (Figures 6 and 7).

The anomalous bottom reflector illustrated in Figure 6 severely handicapped resolution of subbottom information within the upper 3-8 meters of the seafloor. Seismic data collected in other shallow-marine habitats, both before and after the S-92 surveys, and employing the very same equipment and set-up, have not exhibited this same bottom signature. It is therefore concluded that the equipment is not the source of the problem. Two alternative explanations are possible. First, it may be an artifact of boat noise inherent to the survey vessel employed to collect the S-92 lines. Alternatively, it may be a characteristic of the surface geology. Thick, high-amplitude bottom-reflectors occur over very-hard shallow marine habitats such as the cemented carbonate-bank margins of the Bahama Banks (Hine and Neumann, 1977; Boss and Neumann, 1993). High-reflection coefficients in such habitats normally prohibit any subbottom reflectors below the bottom, because almost all the seismic energy is reflected. This produces a reflection-free seismic image below the seafloor. The transparent seismic facies commonly found immediately below the bottom reflector in the S-92 survey area implies the seafloor is indeed extremely hard; no reflected energy is returned from this zone. However, many reflection events are observed at depths below the transparent zone, and this indicates ample seismic energy is being transmitted past the seafloor.

Future seismic surveys will employ different research vessels. Each research vessel emits its own unique and characteristic noise. If the anomalous bottom signal persists in data collected from different vessels within the sand resources survey area(s), then the only reasonable explanation for the bottom signal is the inherent surface geology of the survey area.

Small, truncated channels and other internal reflectors are observed in some instances where shallow subbottom seismic information is imaged immediately beneath the shoals. The truncated nature of the internal reflectors, coupled with the possibility that these features are characterized by a very-hard seafloor, collectively indicate the shoal features are erosional in origin. That is, if the shoals were homogeneous sand bodies, then they would not exhibit many internal reflectors — and especially not truncated channel features. These structures therefore imply the topography of the shoal features is a product of erosional patterns, rather than large, unconsolidated, actively-migrating sand bodies. If this is true, it would deflate their value as potential sand resources.

Although many relict stream valleys have been identified in the S-92 data set, the density of data collected and interpreted to date is insufficient to permit projecting or mapping specific channels between seismic lines. Such features would likely make excellent targets for beach-renourishment resources due to the textural nature of the valley-fill fluvial sands.

SUMMARY AND RECOMMENDATIONS

The work completed under Year 1 funding has established a partial image of the subbottom and surface geology, as well as position and size of local shoal features within the study area. It provides a good fundamental start toward establishing a 3-dimensional stratigraphic framework for subsequent resource assessments. However, additional seismic data are required before an internally-consistent geologic framework is established, the subbottom geology evaluated, and a list of targets to be sampled by coring are tabulated and ranked in accord with the priorities of the NC/MMS Sand Resources Task Force.

The interpreted, scale-rectified, and reduced seisections depict several large shoals overlying a stacked series of tabular stratigraphic units. Each stratigraphic unit is 6 to 20 meters thick, and all

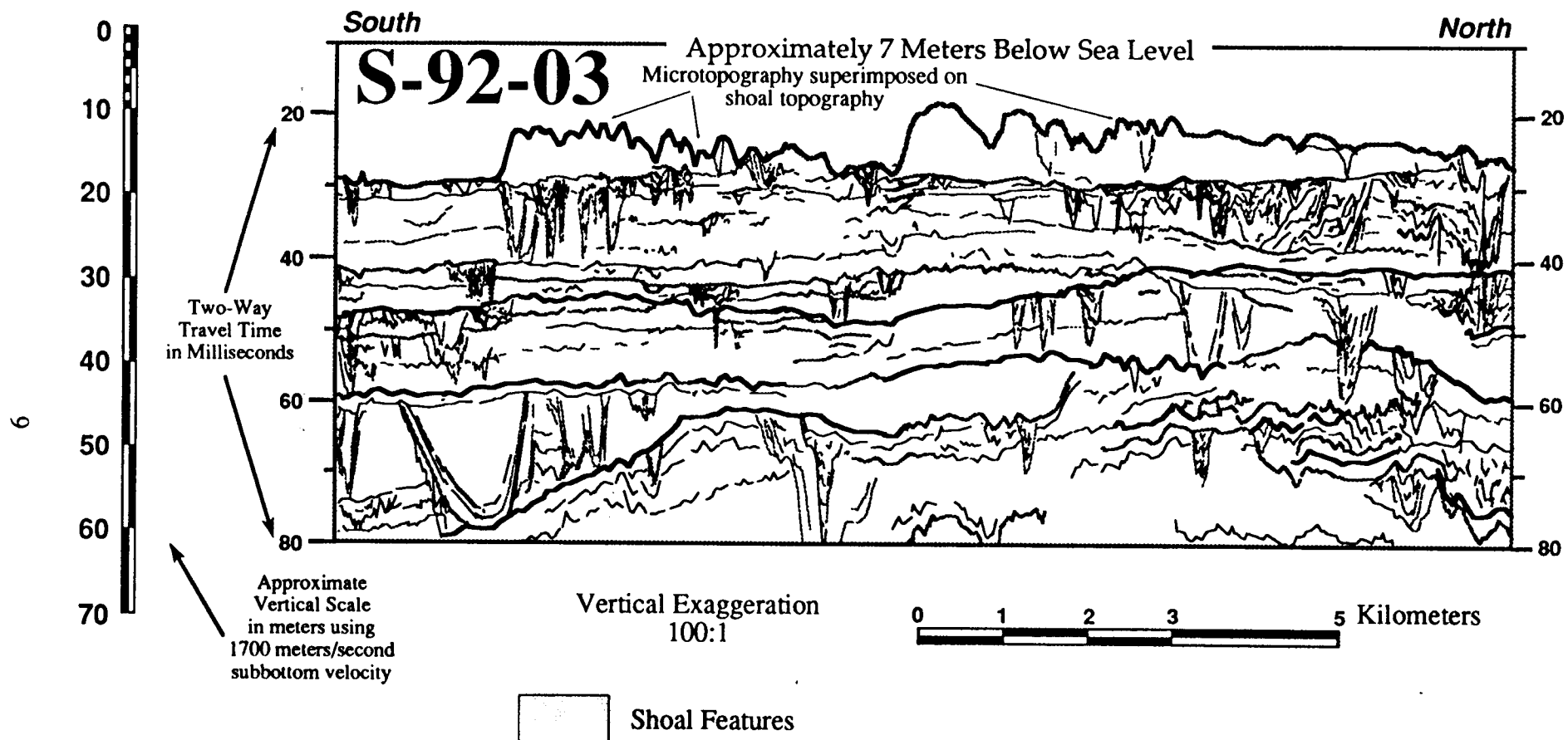


Figure 5. A segment of seisection S-92-03 showing the superposition of topographic features associated with the continental shelf shoals identified within the S-92 survey area. See seisection S-92-03 in Appendix A for reference to the location of this section.

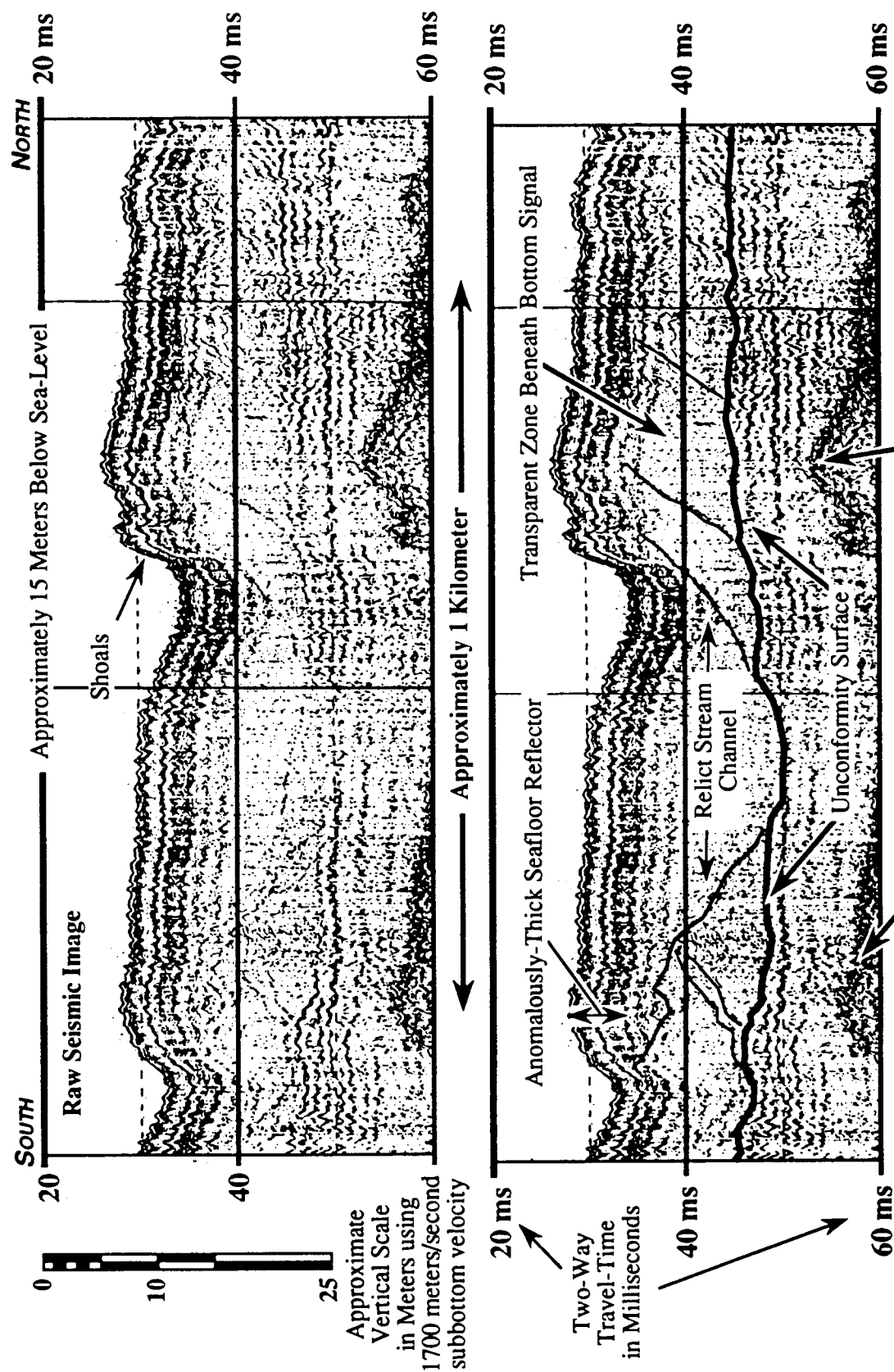


Figure 6. Seismic data exhibiting the anomalously-thick seafloor reflector and seismically-transparent zone(s) associated with the shelf-shoal features identified within the S-92 survey area. Upper panel presents the raw seismic image which is duplicated and annotated in the lower panel. The location of this profile is shown in Figure 7.

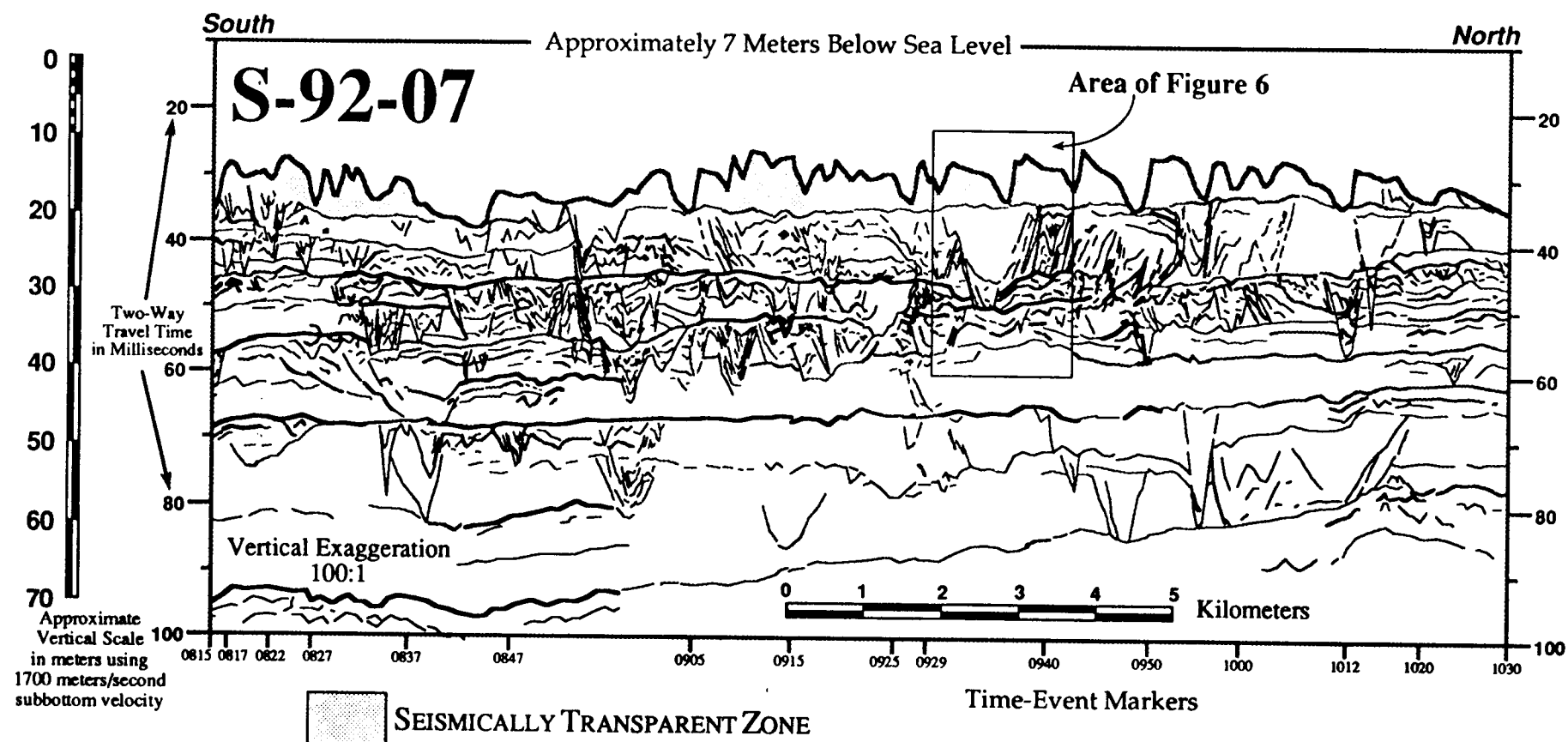


Figure 7. Seissection S-92-07 which illustrates the seismically-transparent zone underlying the shelf-shoal features identified within the S-92 survey area. The location of seissection S-92-07 is shown in Figure 2 and Appendix A.

are bounded by unconformity surfaces cut by multiple, relict (buried) stream valleys. The shoal features exhibit 3 to 15 meters of topographic relief, are common at water depths greater than 20 meters, and appear to be erosional in origin. The shoal bodies, in addition to anticipated near-surface paleofluvial channels, remain the primary features of interest. But, additional data are required to identify specific vibracore targets within the survey area.

Recommendations for future work, ranked in order of priority, are as follows.

(1) Complete the seismic-survey grid for the area off Nags Head and Kitty Hawk; interpret and reduce that data to seisections consistent in format with the existing data.

(2) Develop a detailed, three-dimensional, geological framework for the survey area. Map-out the subbottom seismic sequences, sites of all near-surface channels and their thalweg tracks, and the position and aerial extent of the large shoal features.

(3) Tie the stratigraphic information presented in the seisections to all existing cores, boreholes, or other geologic information, in order to forecast the lithologies of the seafloor outcrops prior to coring.

(4) Concurrent with tasks 1 through 3, integrate all existing data into a GIS data base for easy access by all interested parties, as well as annual updates via incorporation of new data.

ACKNOWLEDGEMENTS

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Charles W. Hoffman, Richard C. Dentman, and

Mary E. Watson of the North Carolina Geological Survey, Coastal Plain Office participated in various phases of collecting and preparing this data set for release.

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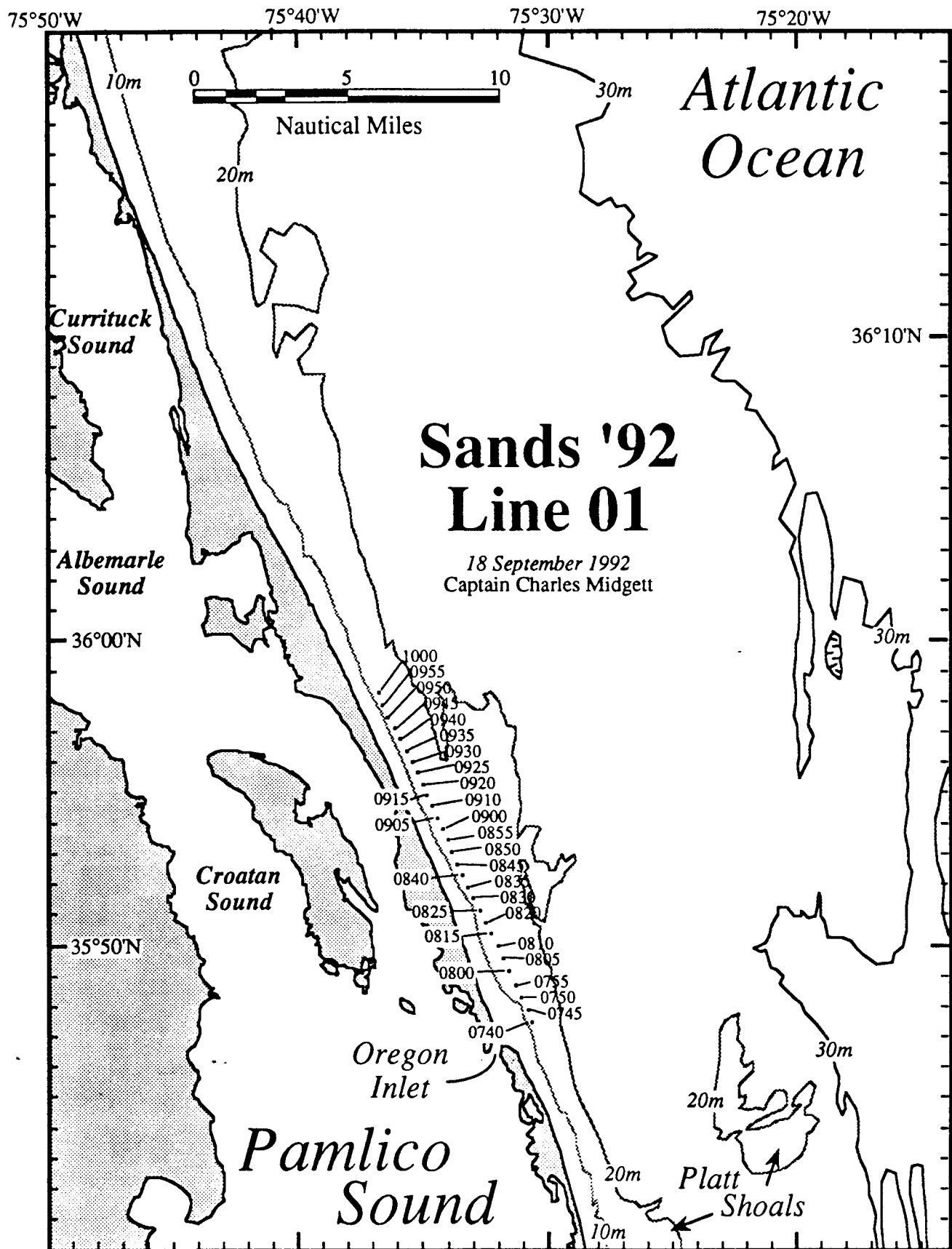
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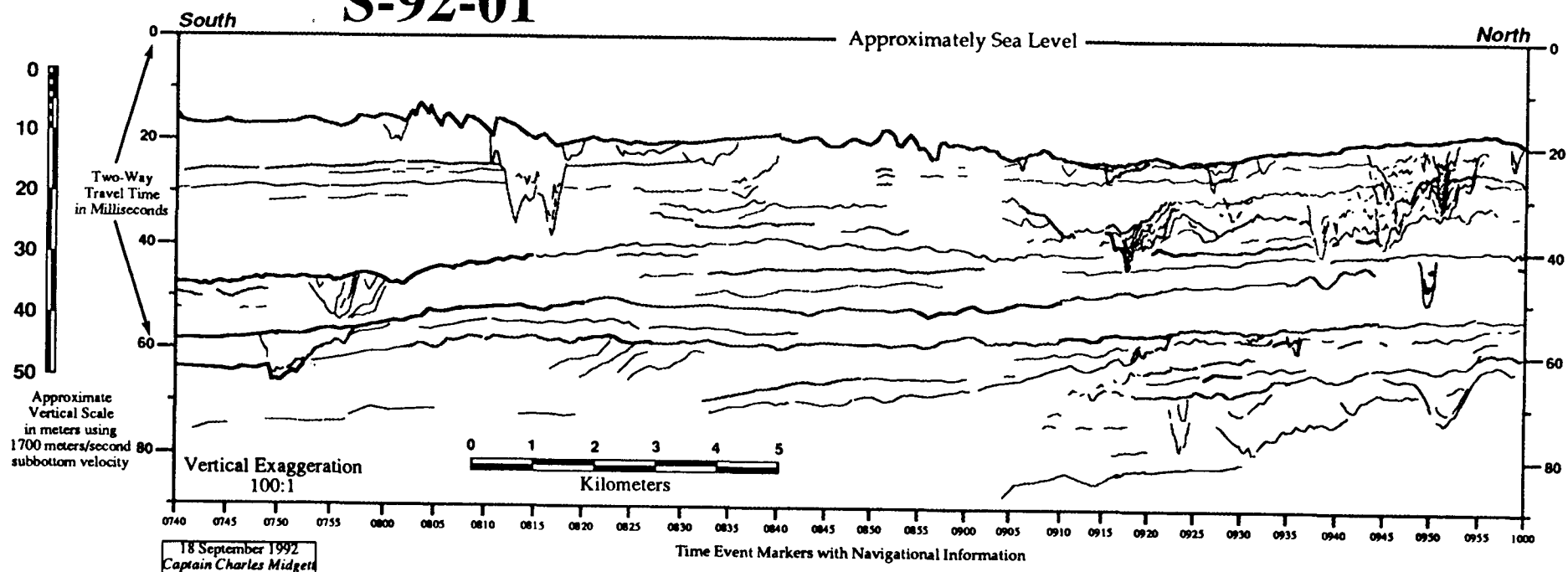
APPENDIX A

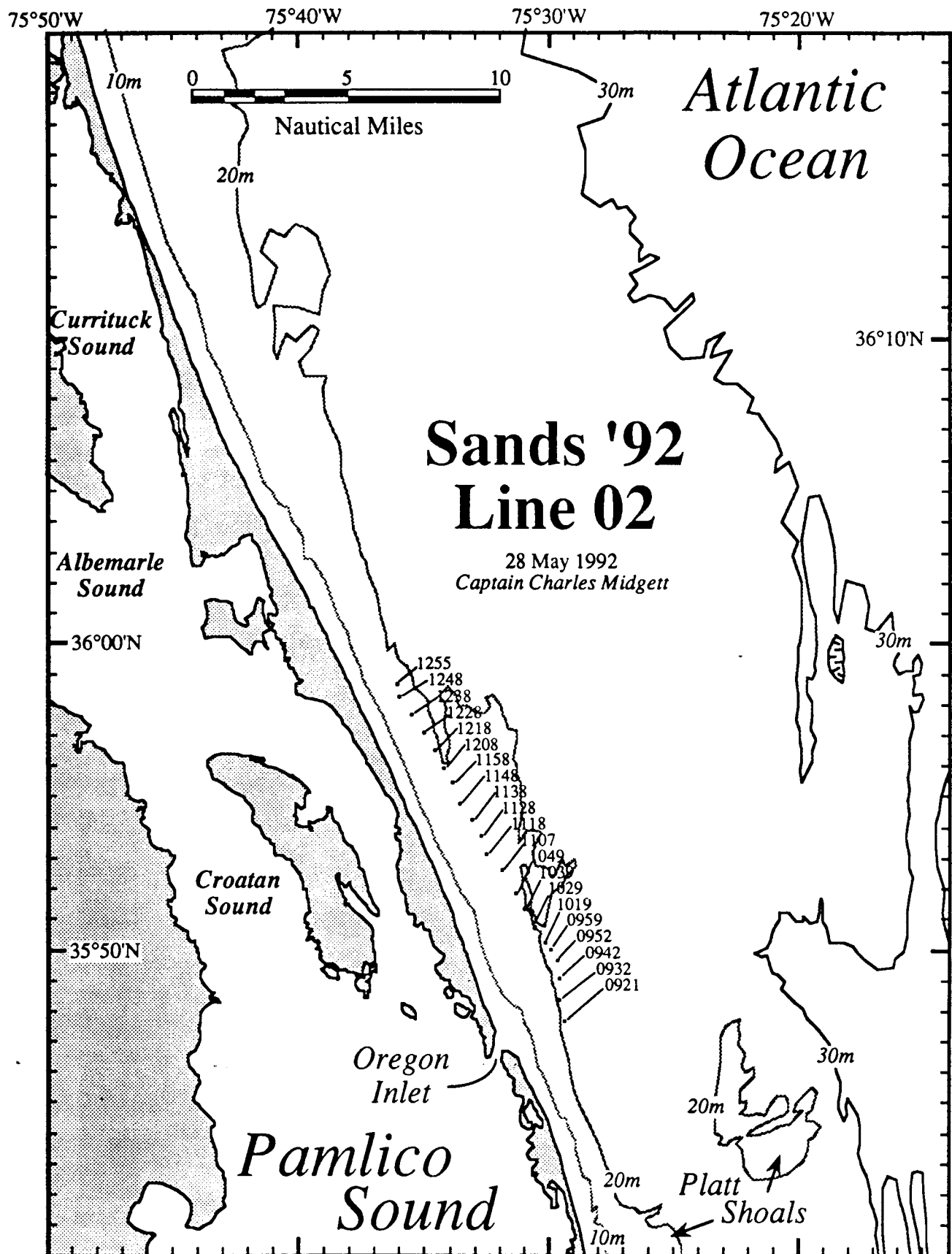
S-92 Seisections and Maps

Each seismic section that has been interpreted, digitized, scale-rectified, and plotted as stratigraphic line-drawings is presented in this appendix. The stratigraphic information is illustrated in 15 separate seisections plotted with a vertical exaggeration of 100:1. Refer to each section for its specific horizontal and vertical scales. Time-Event marks labeled along the base of each line refer to geographic positions labeled on the maps immediately preceding each seisection.

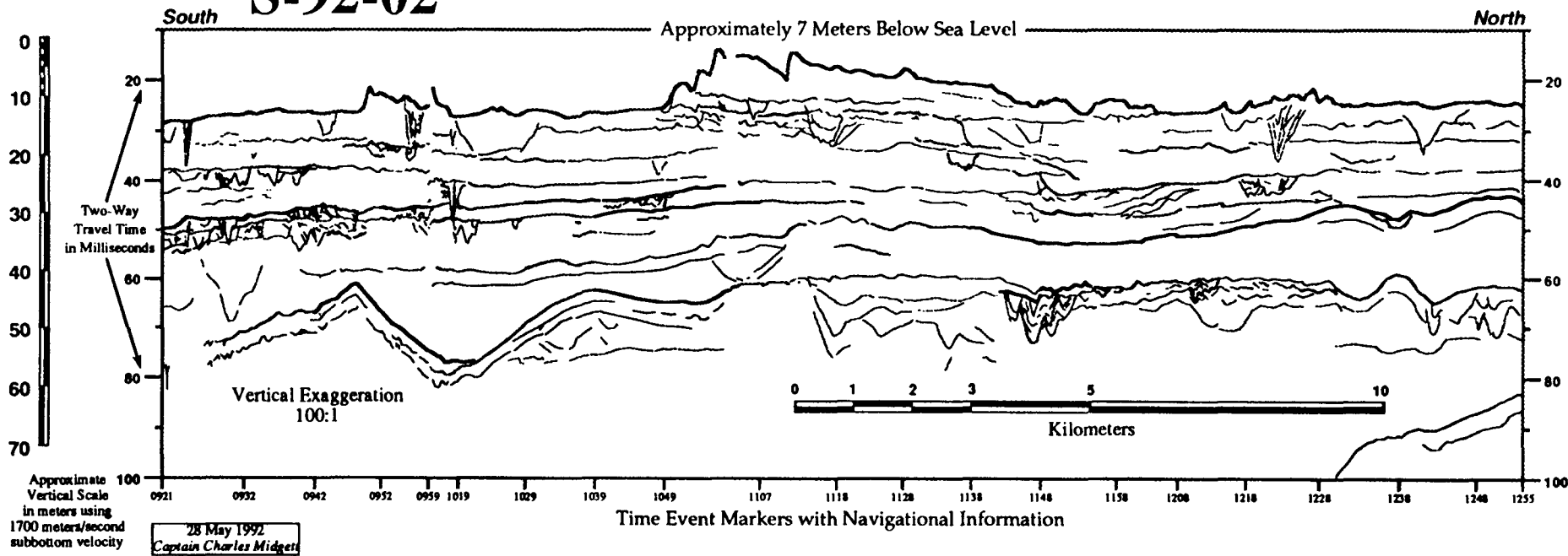


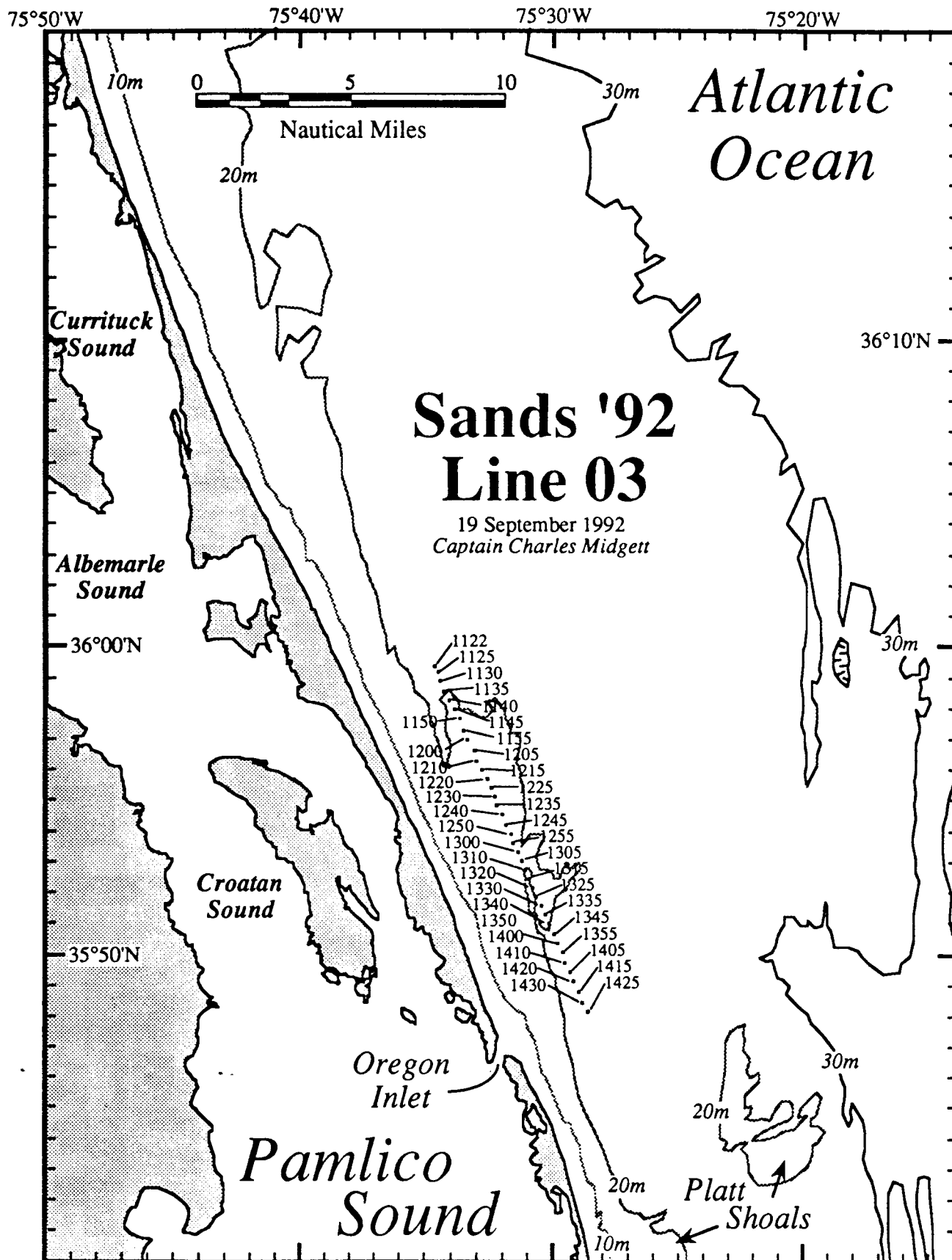
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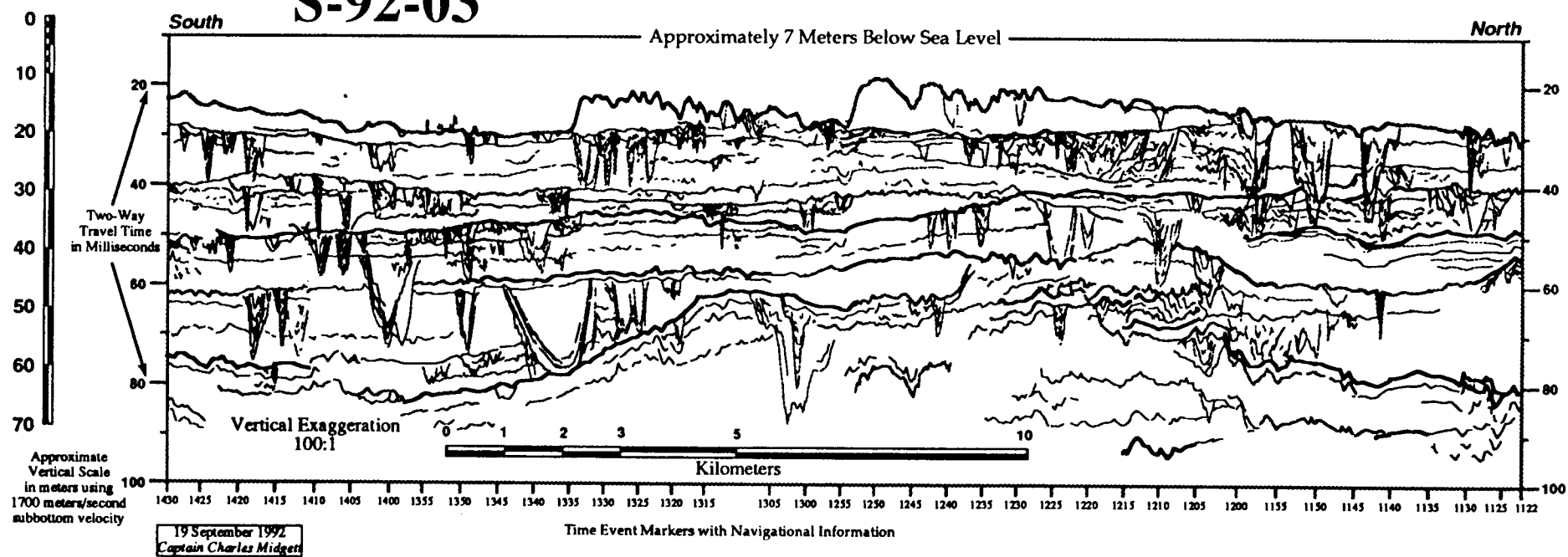


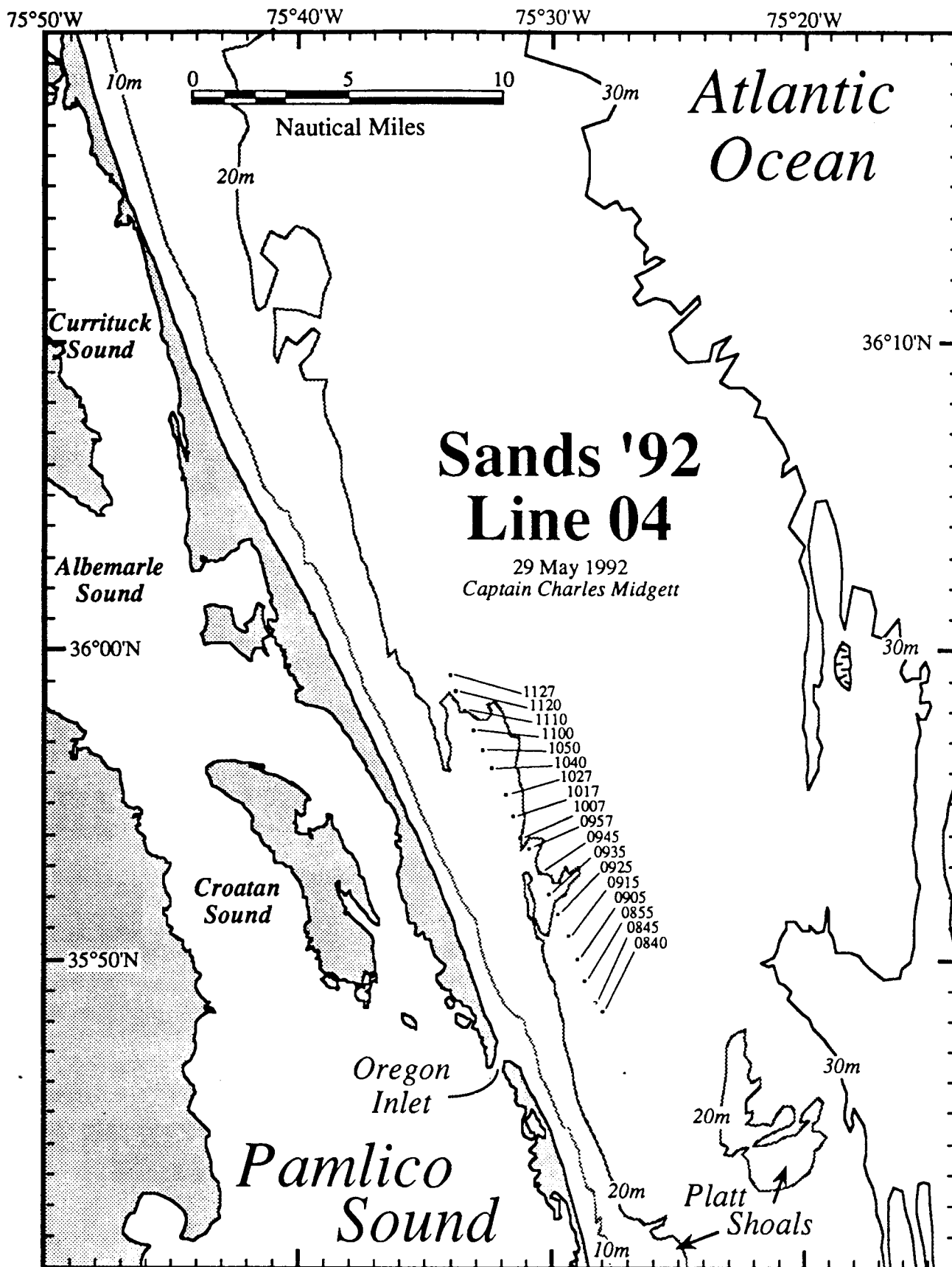
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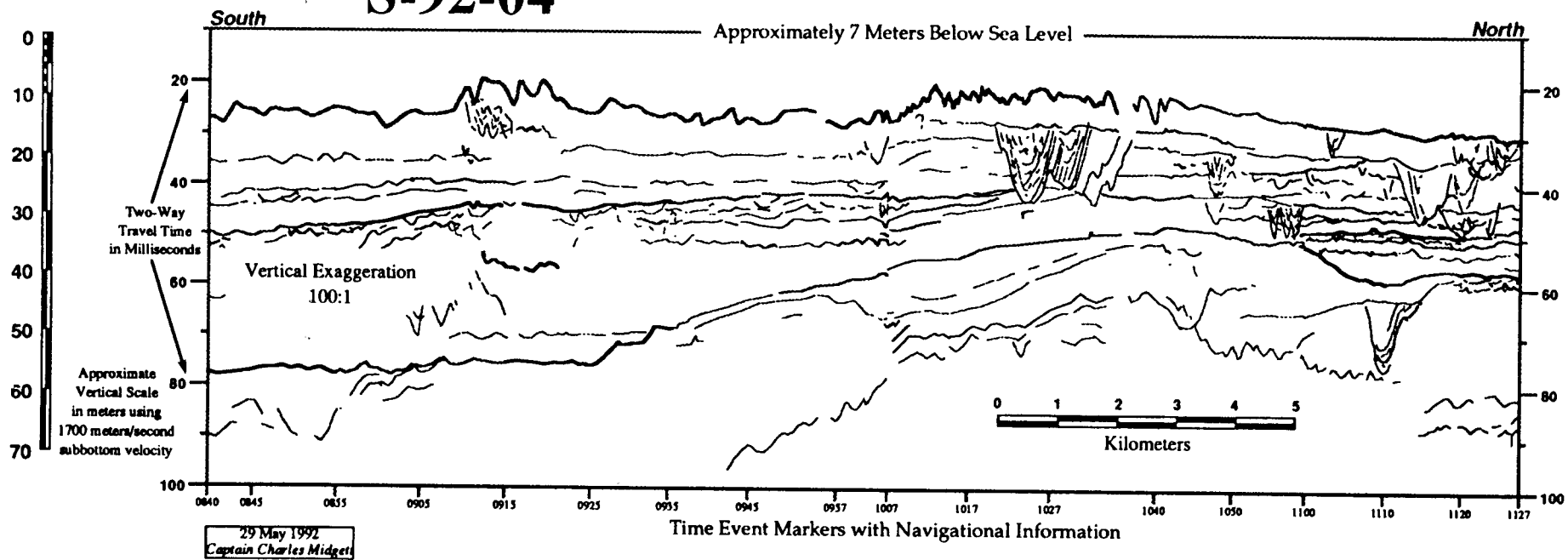


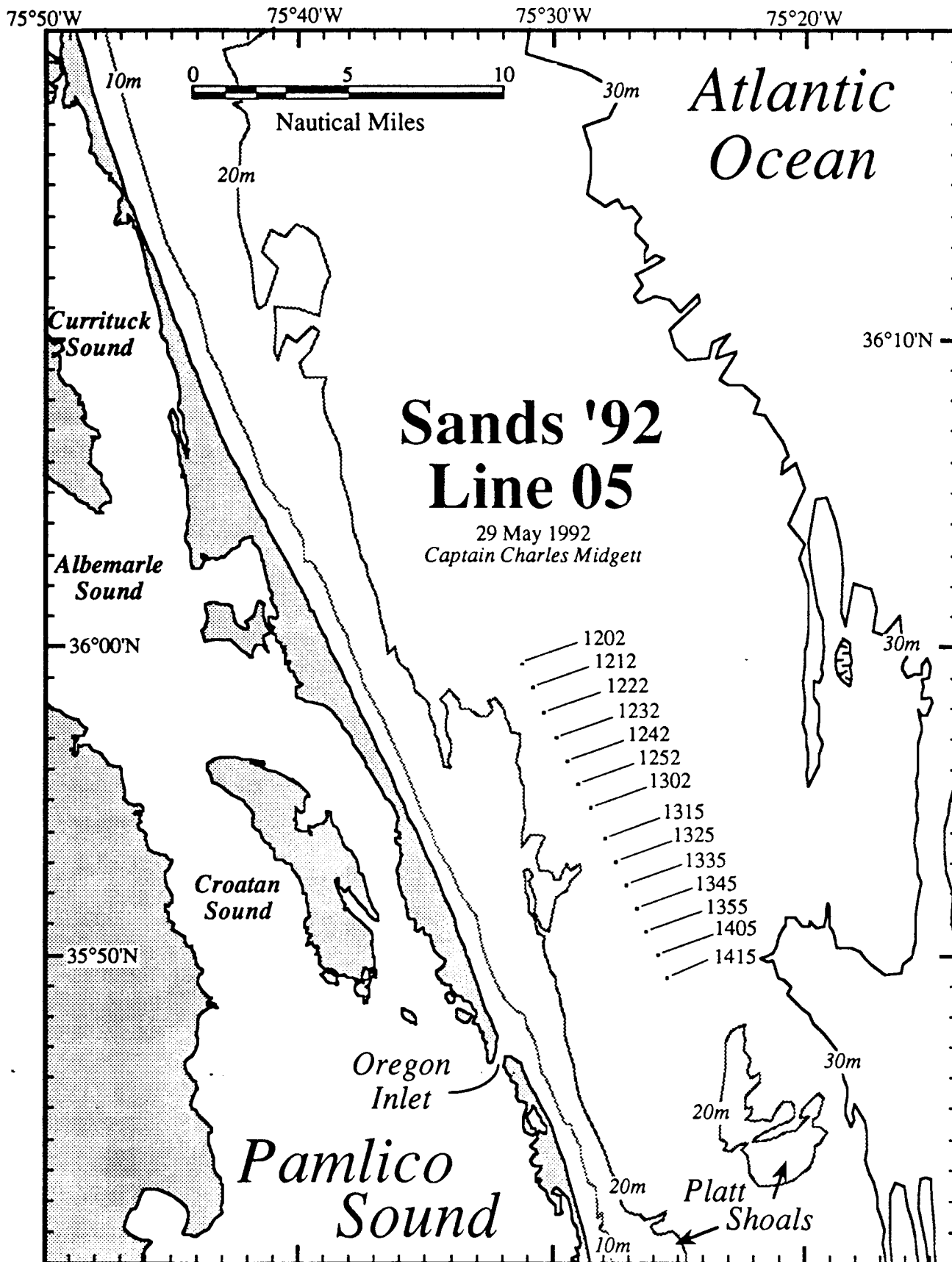
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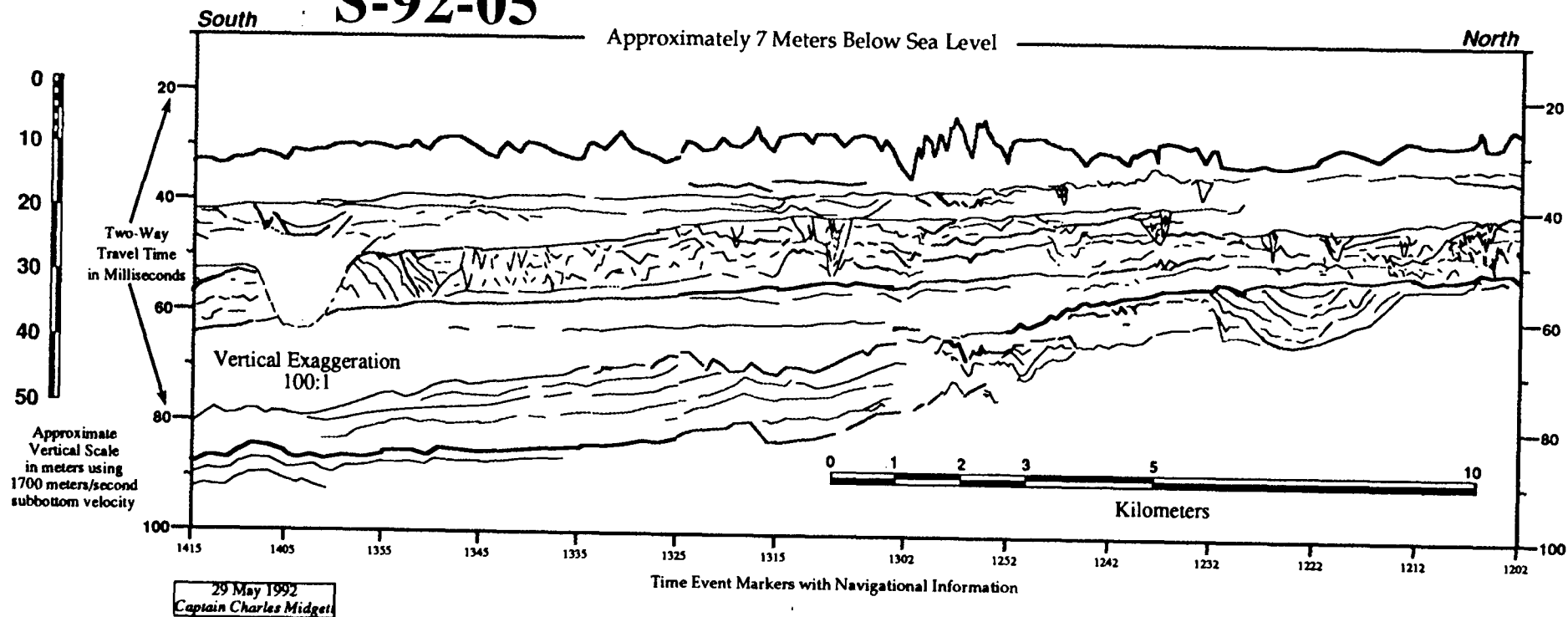


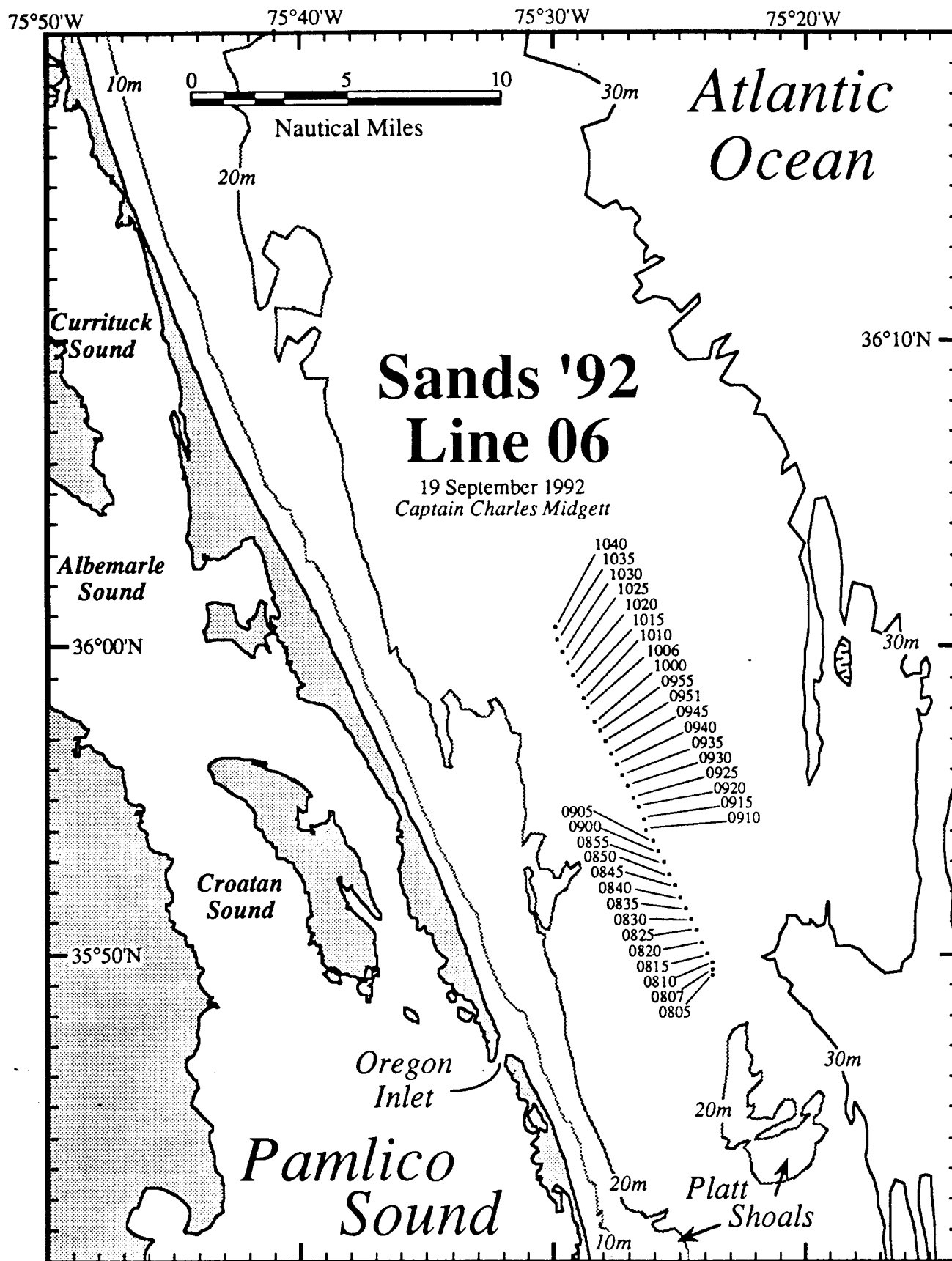
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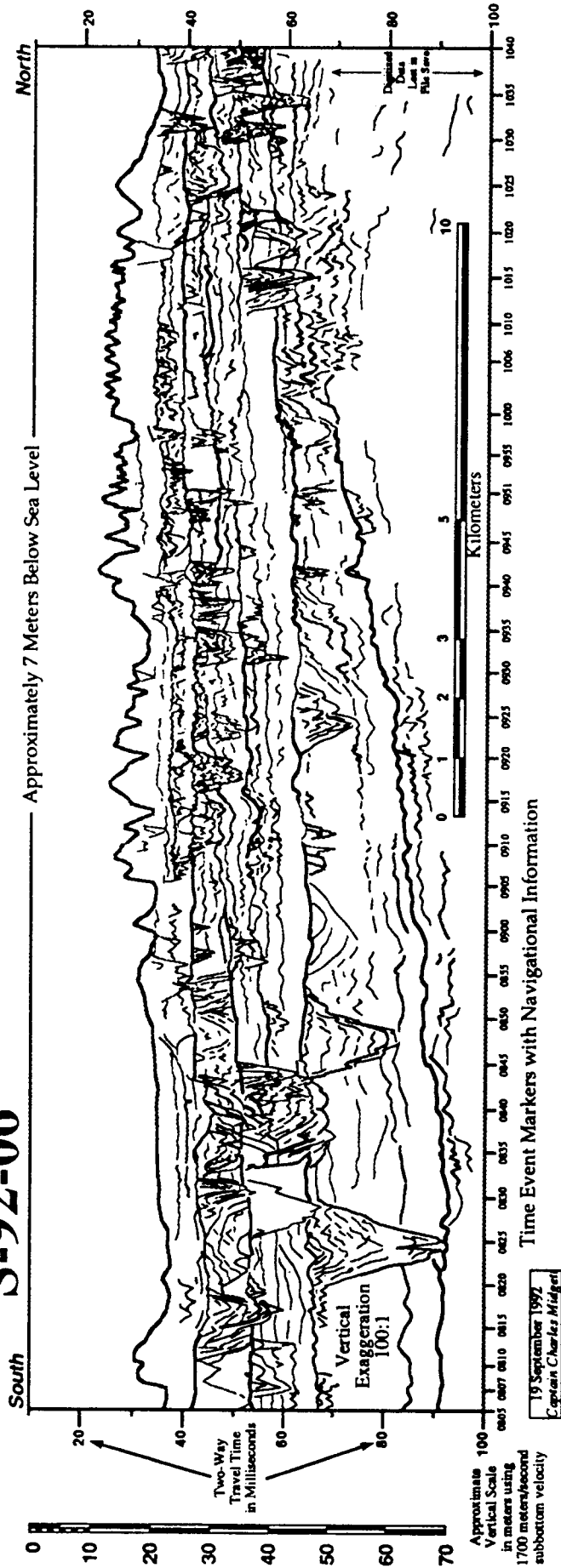


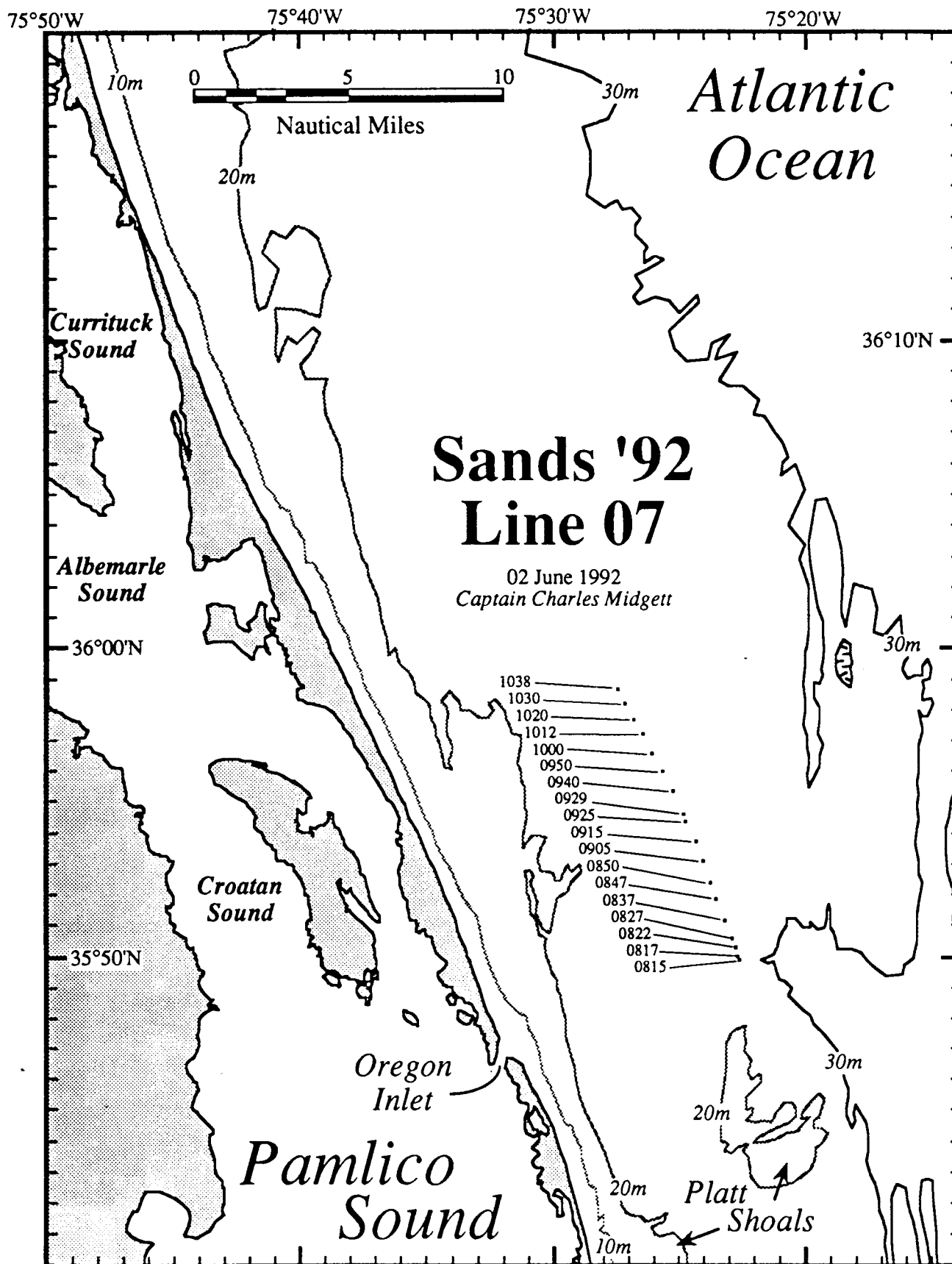
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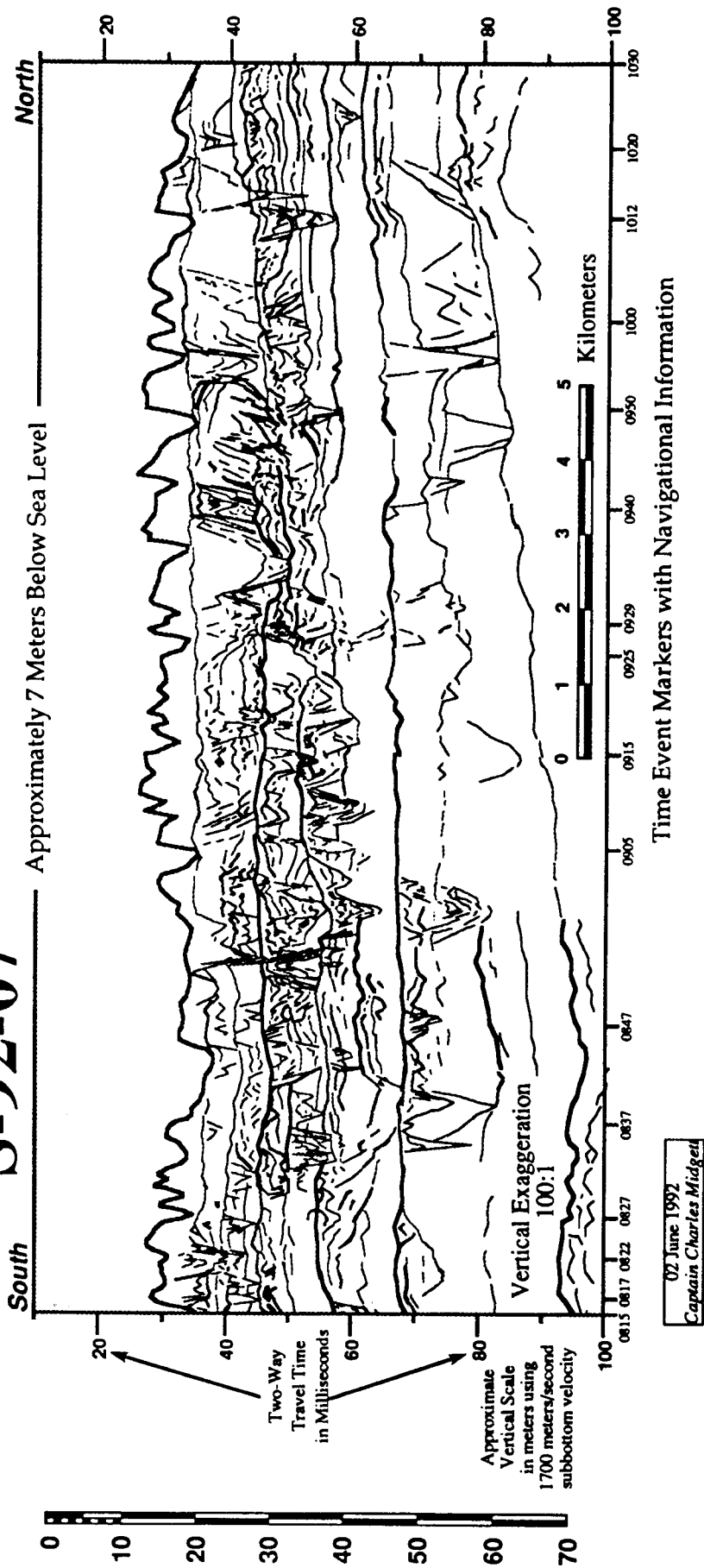


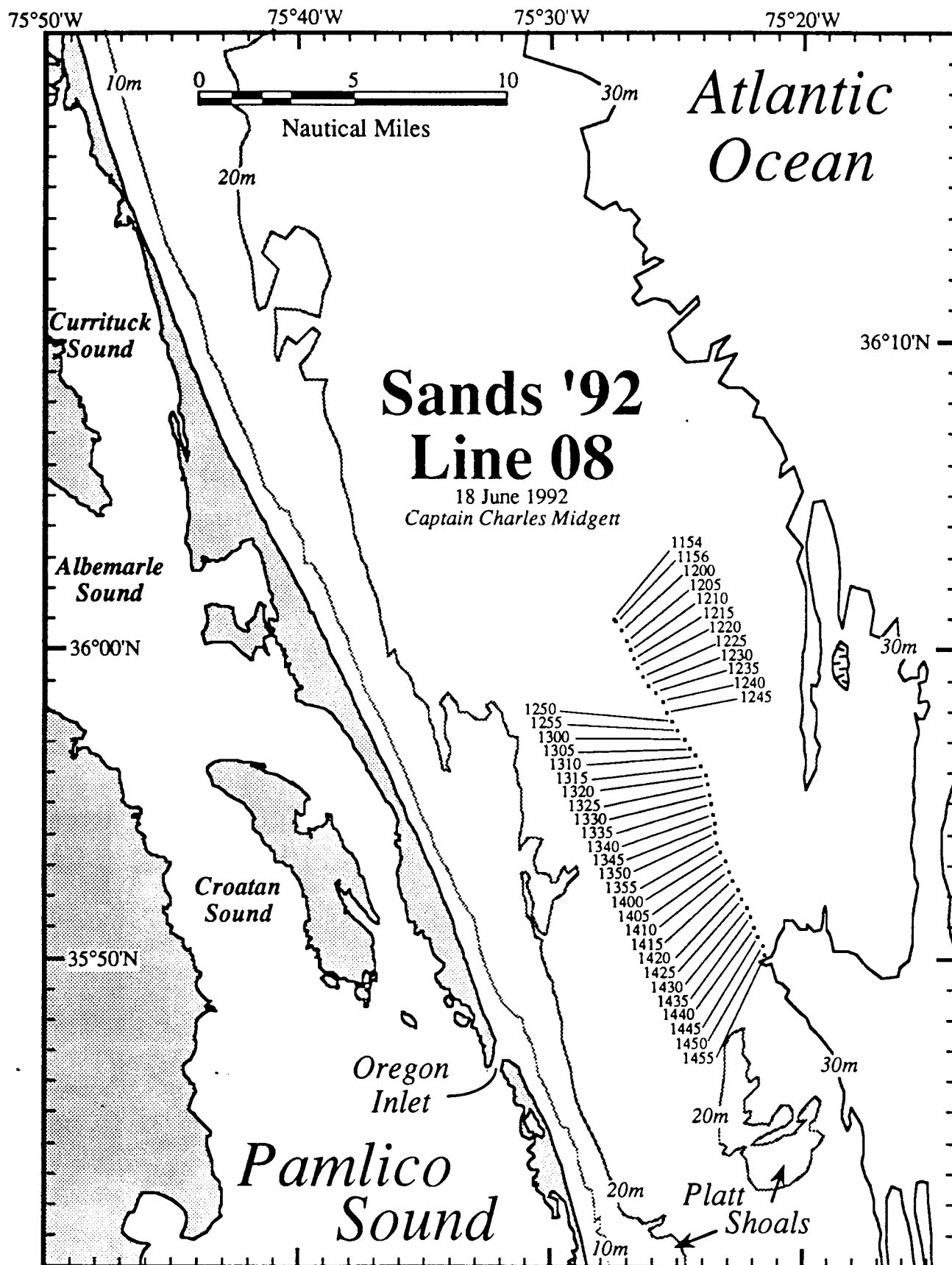
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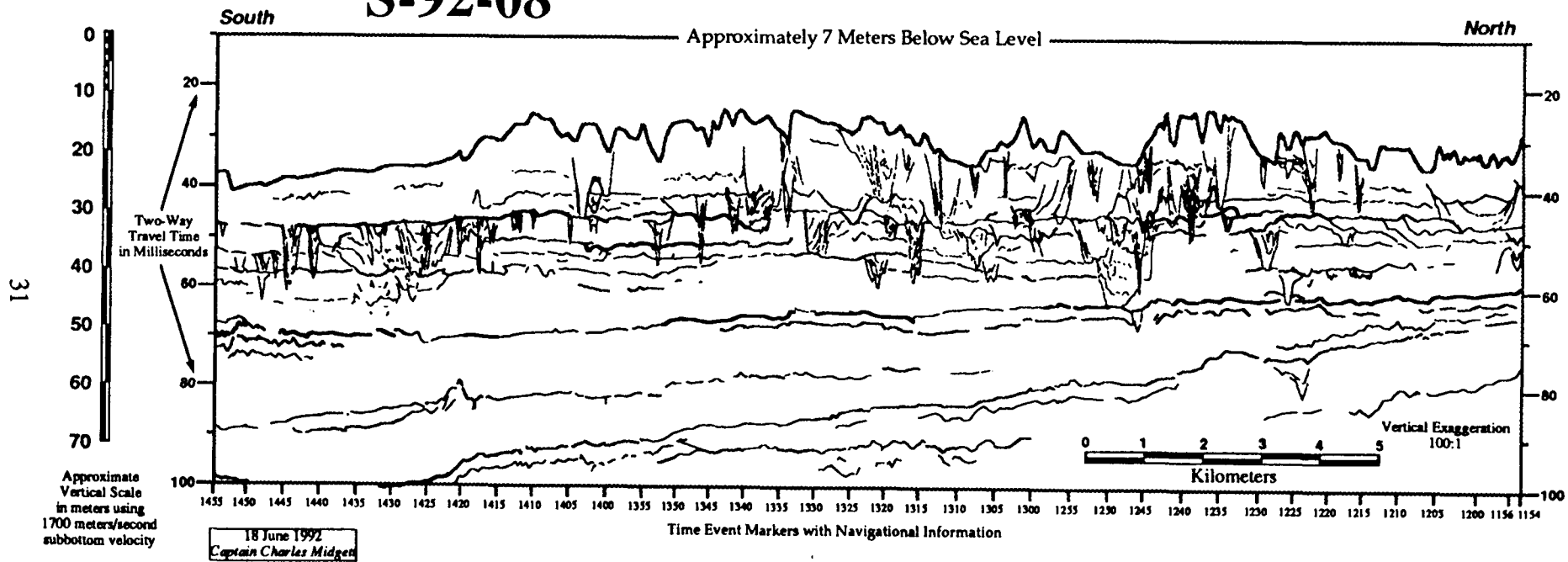


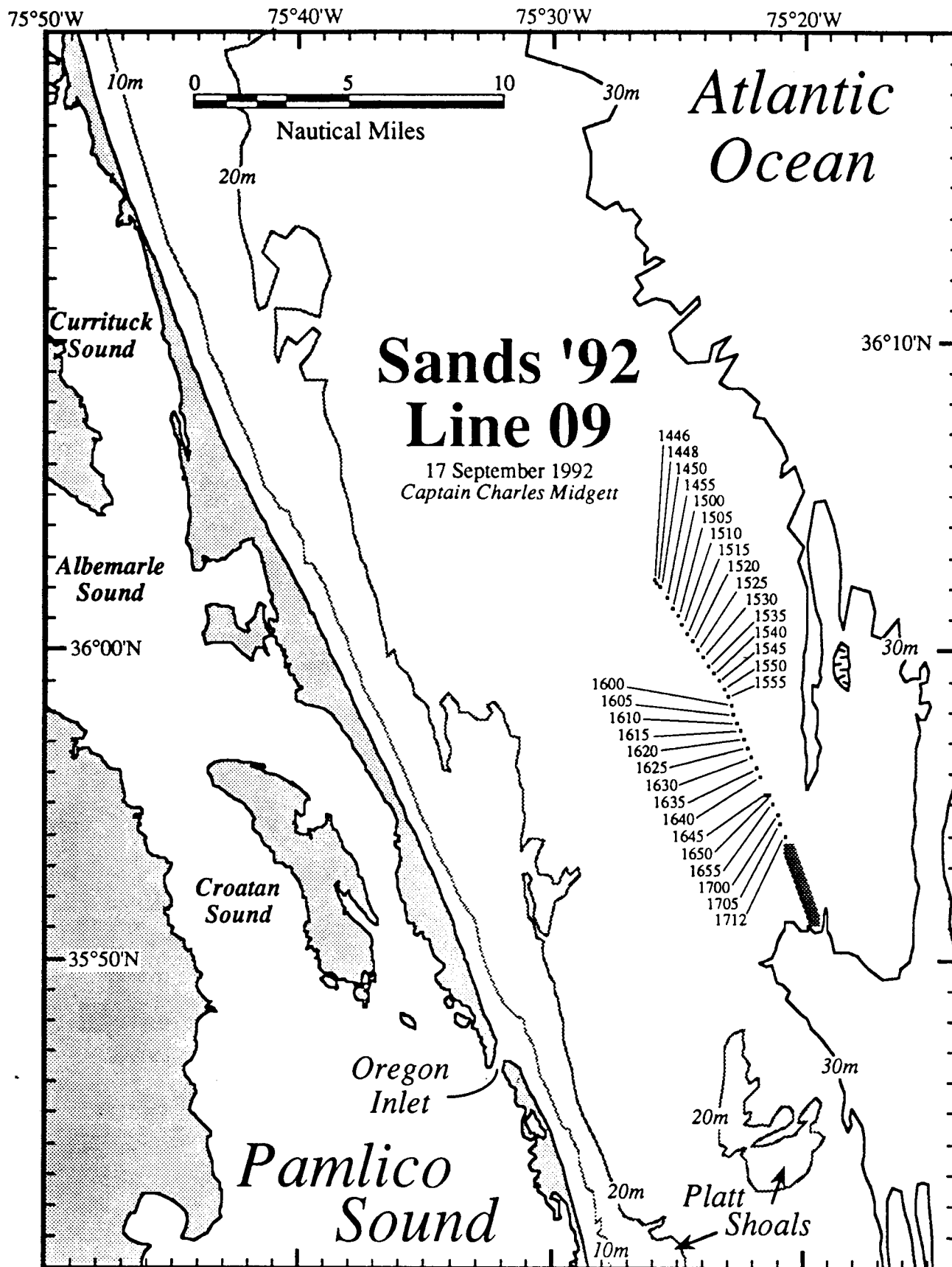
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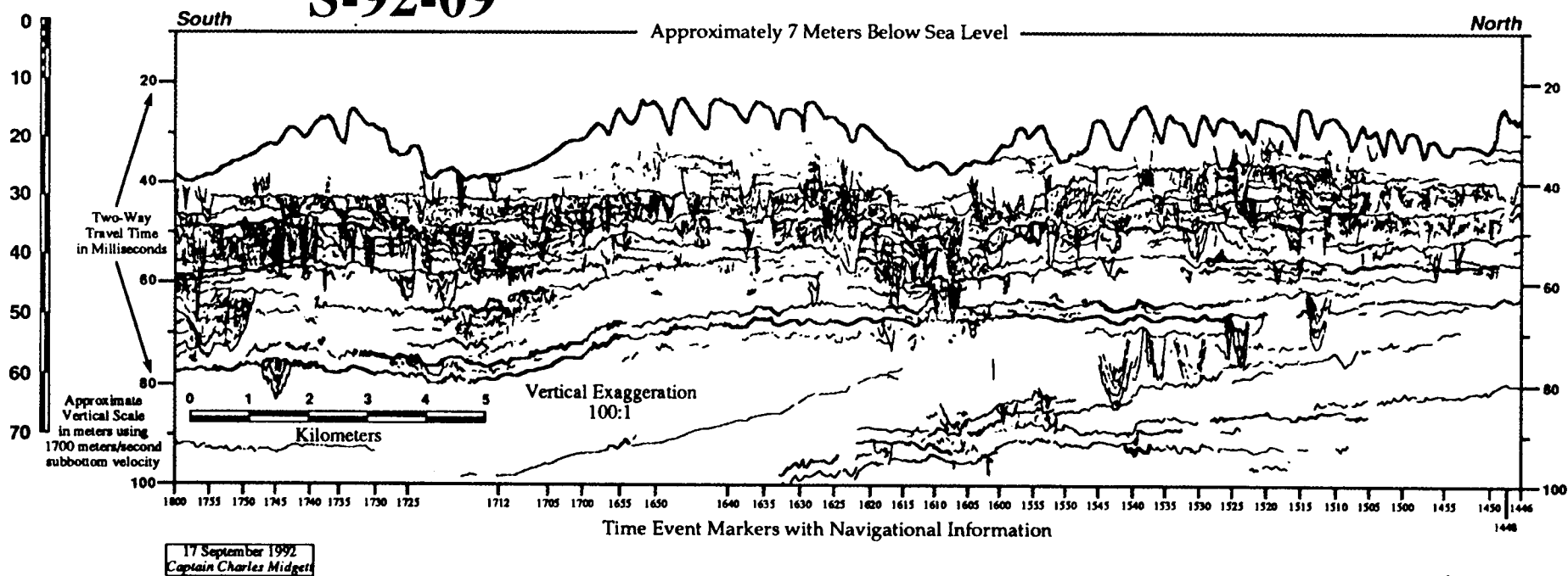


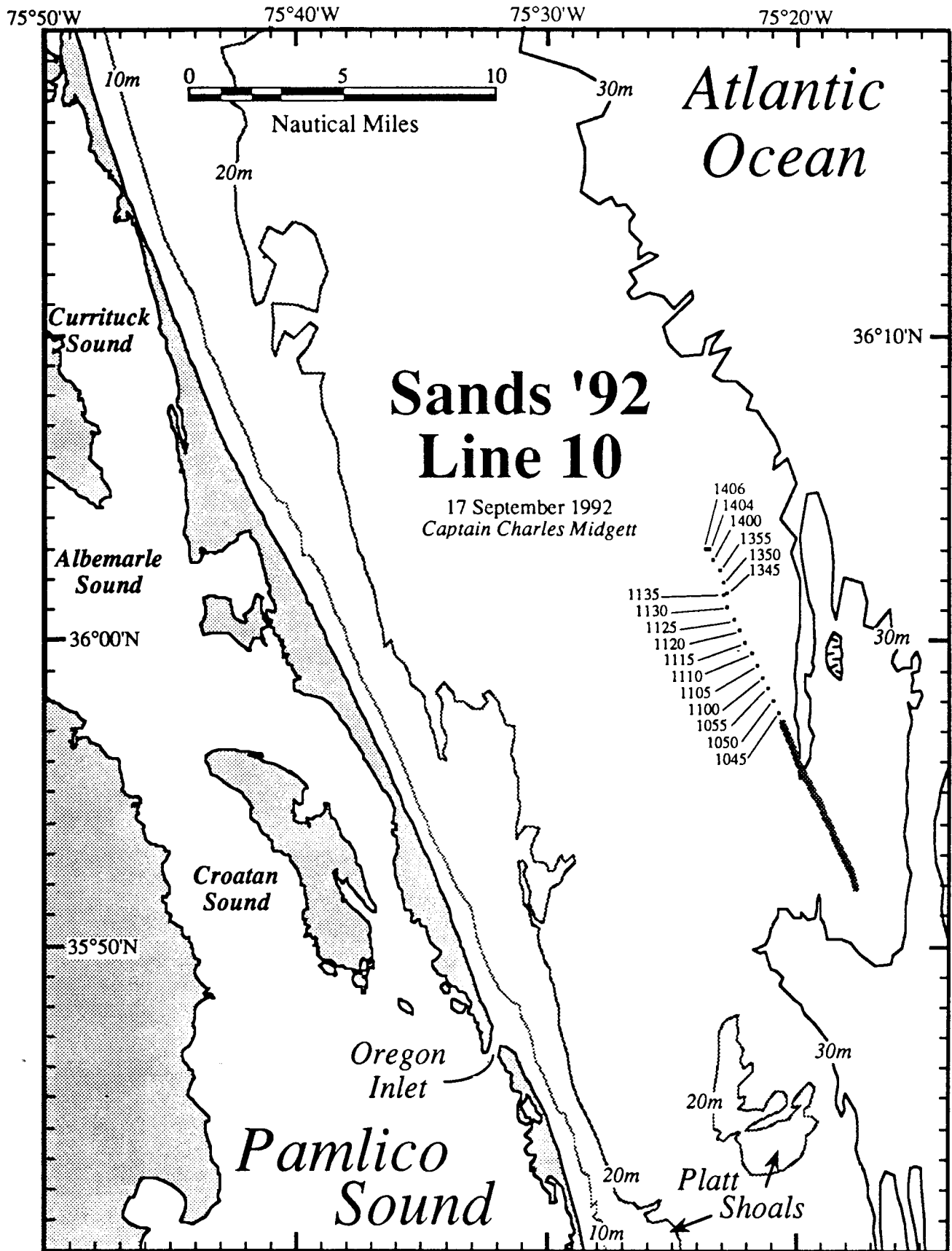
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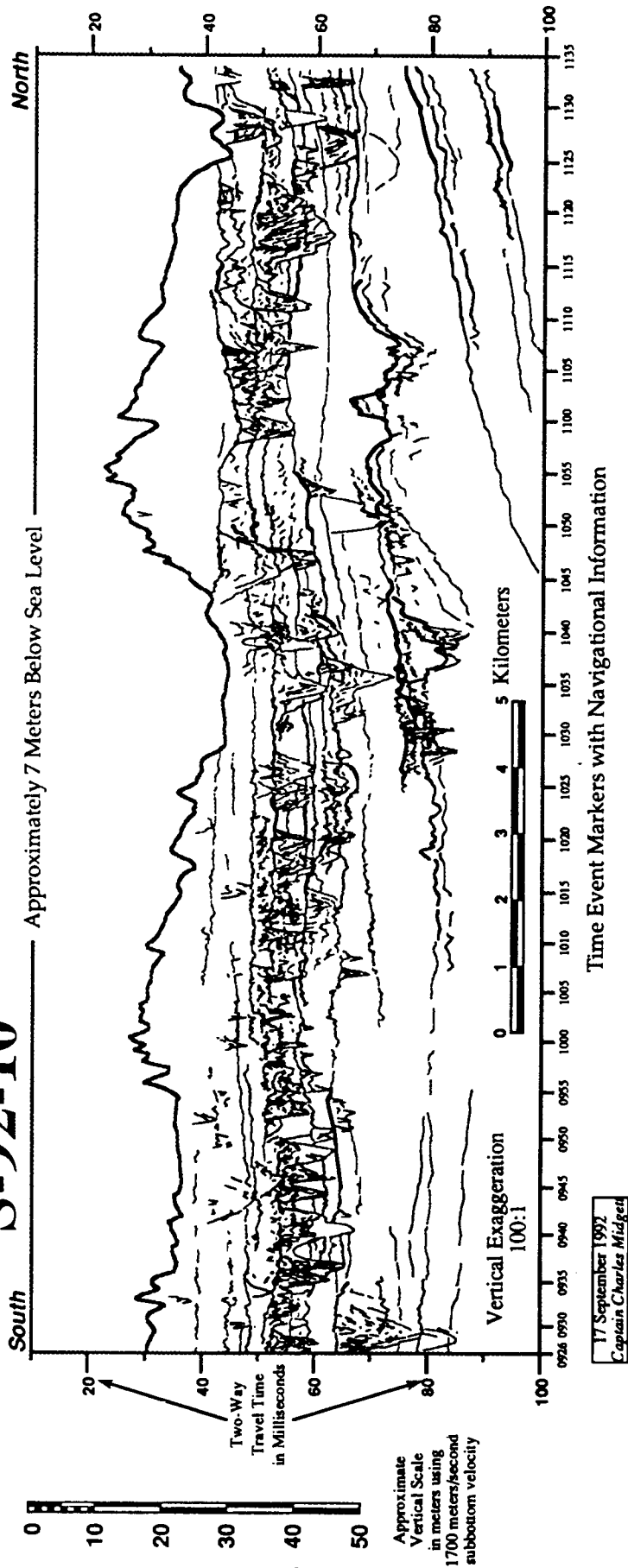


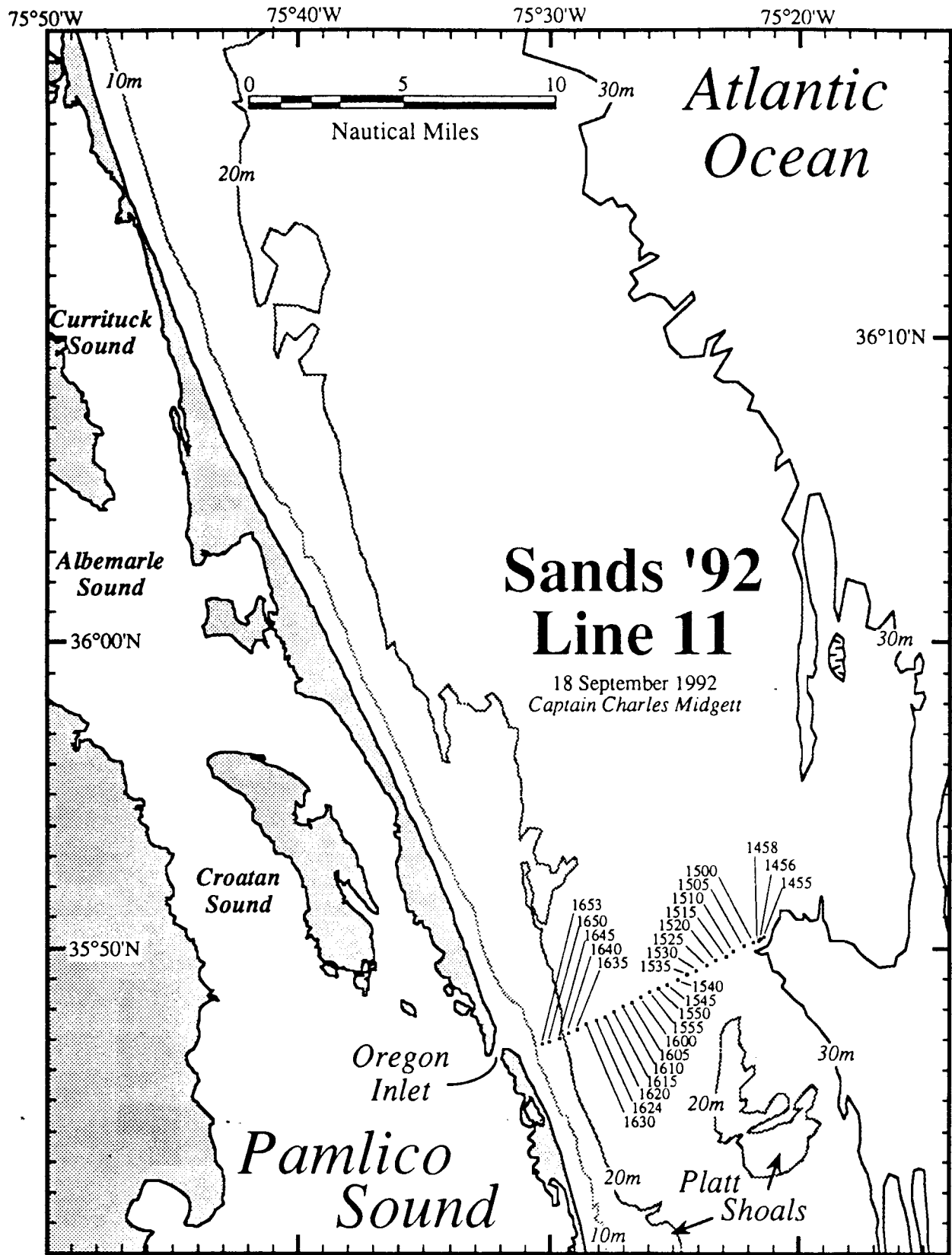
S-92-09



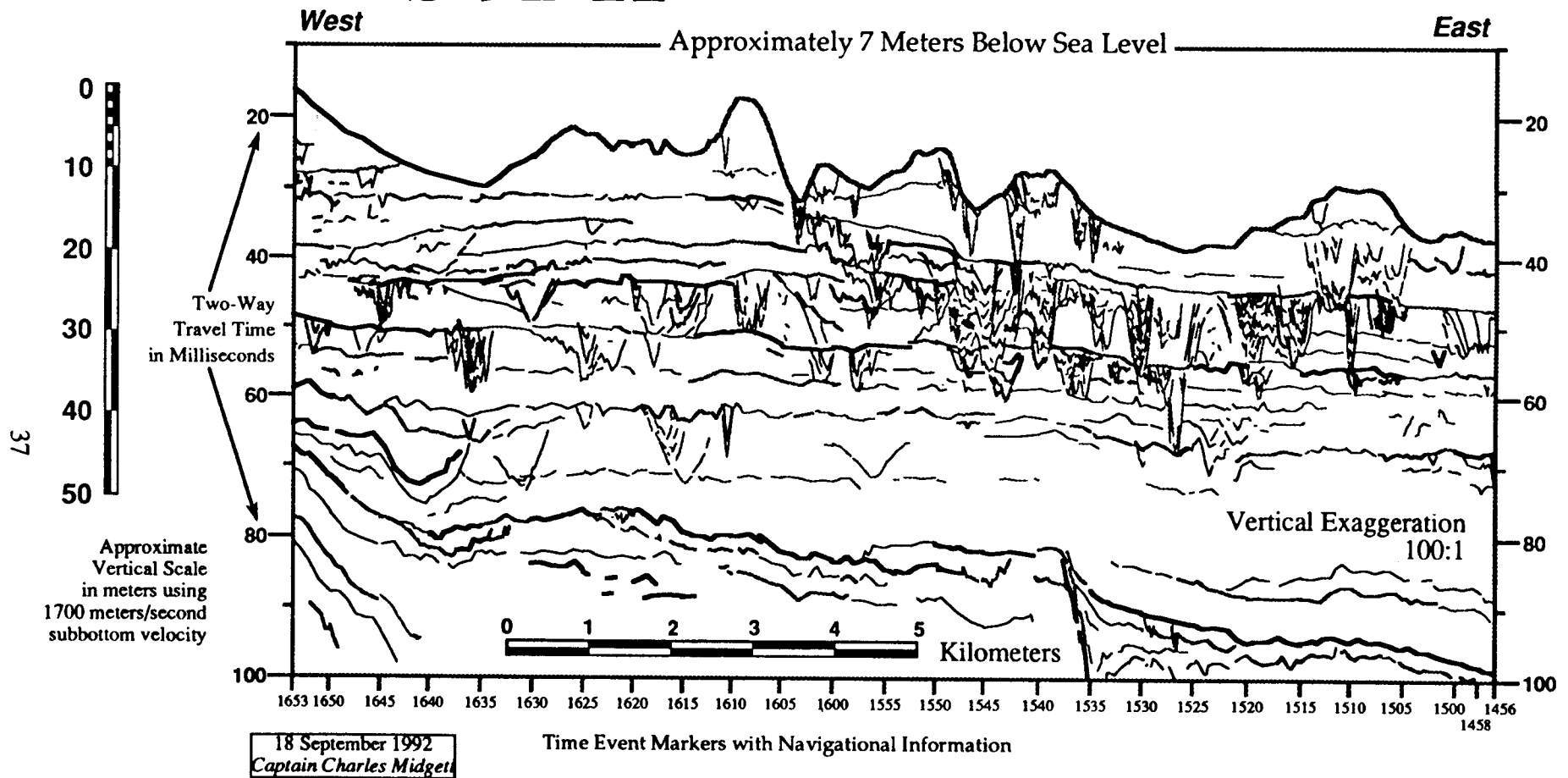


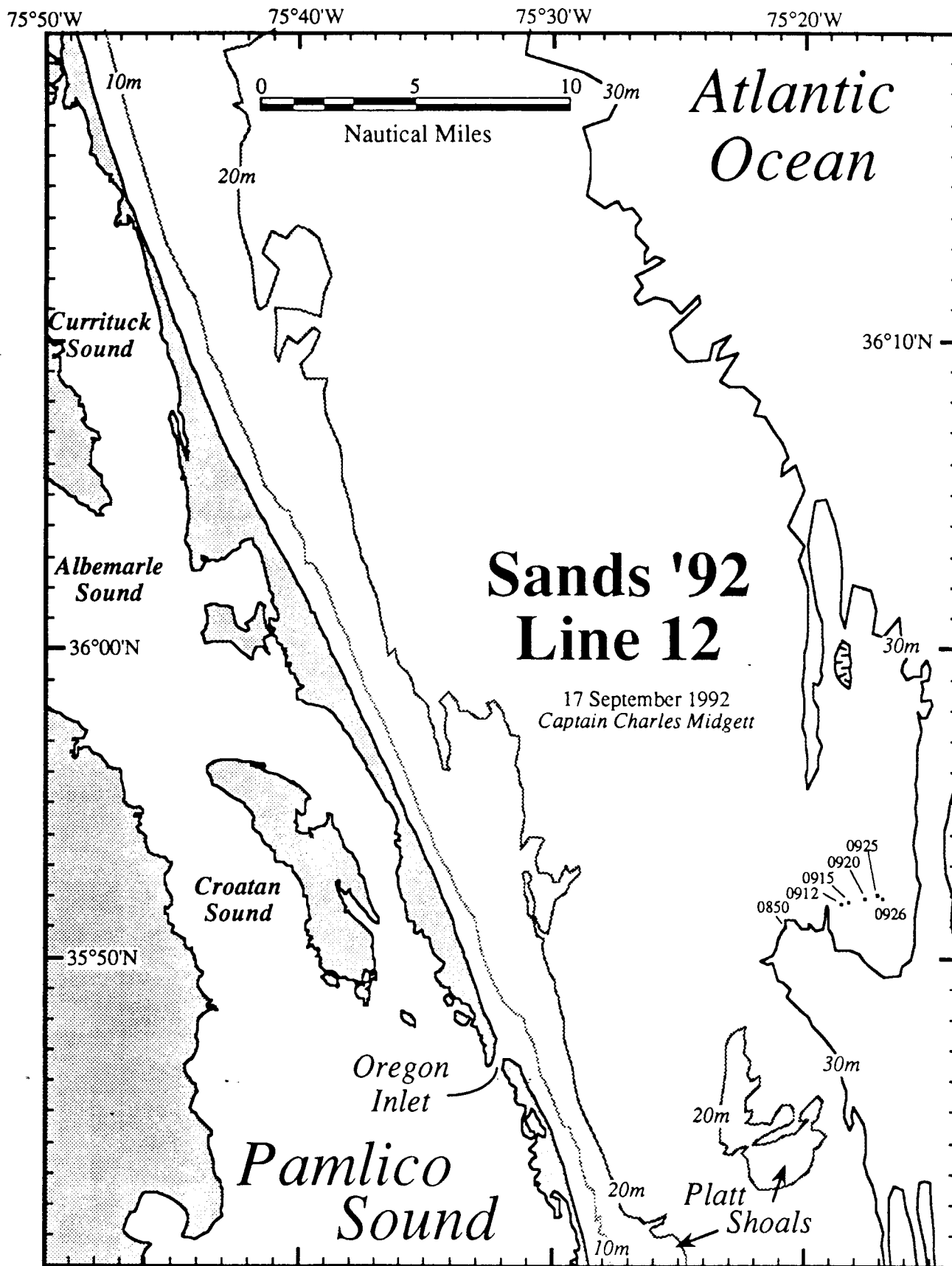
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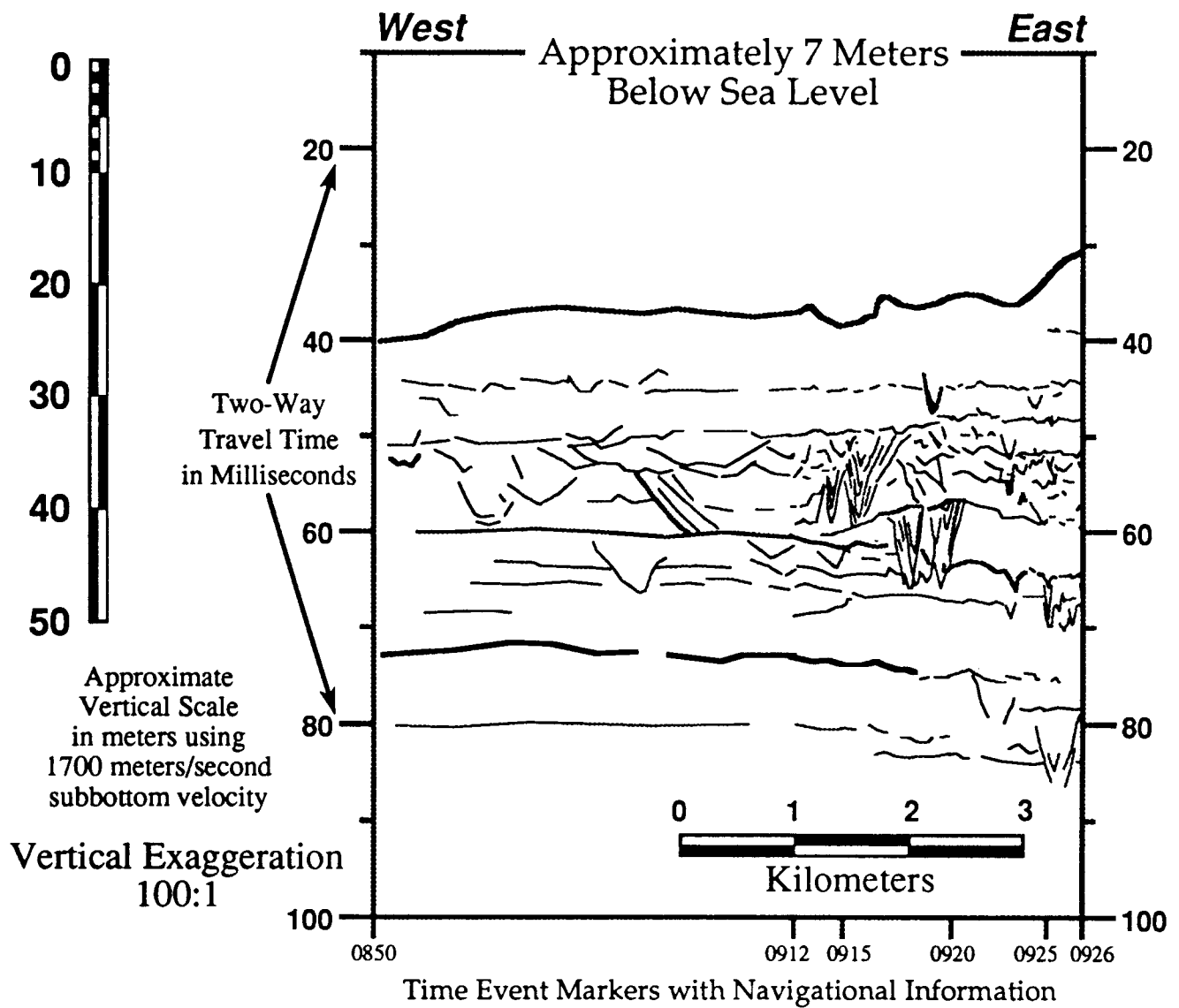


S-92-11

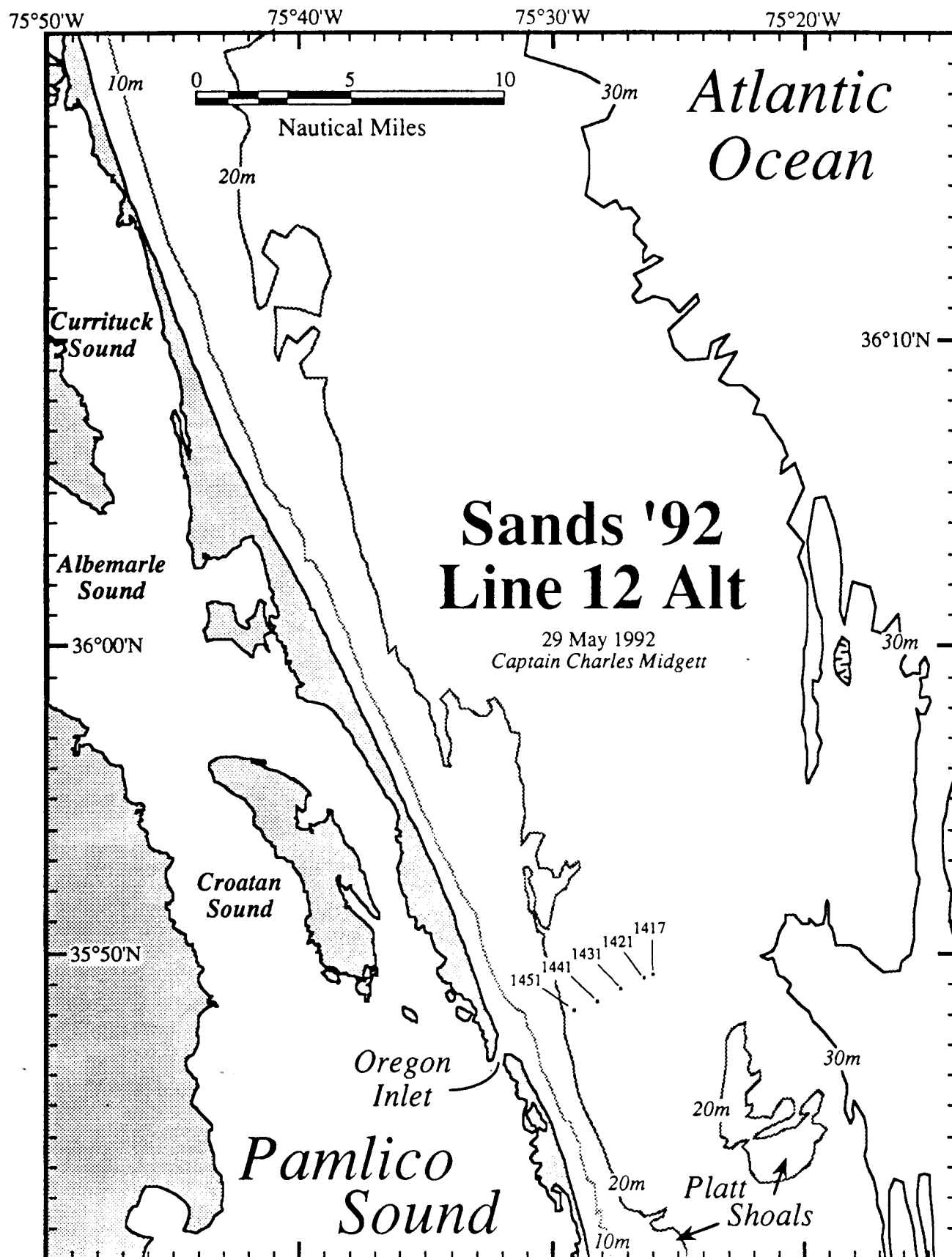




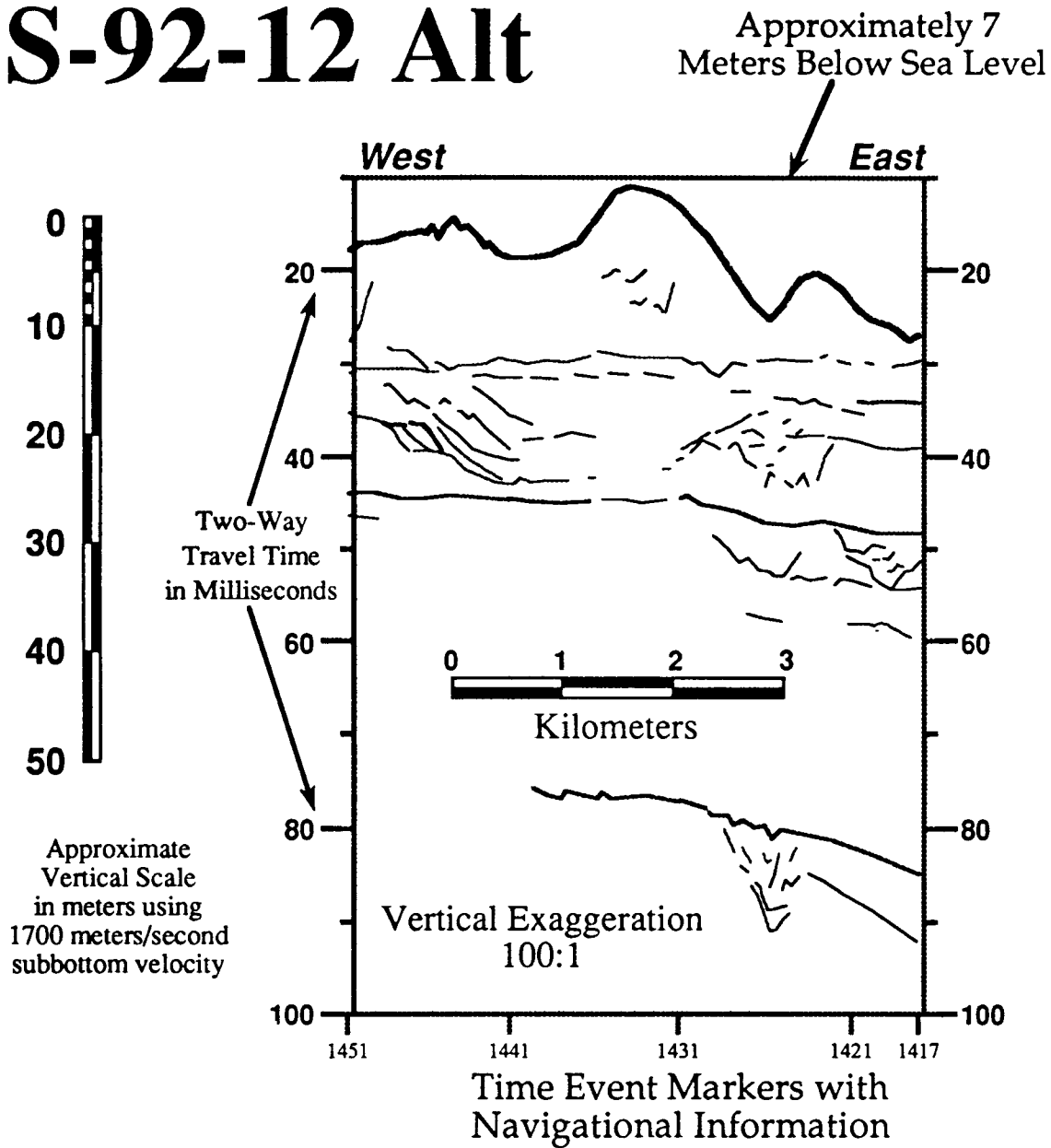
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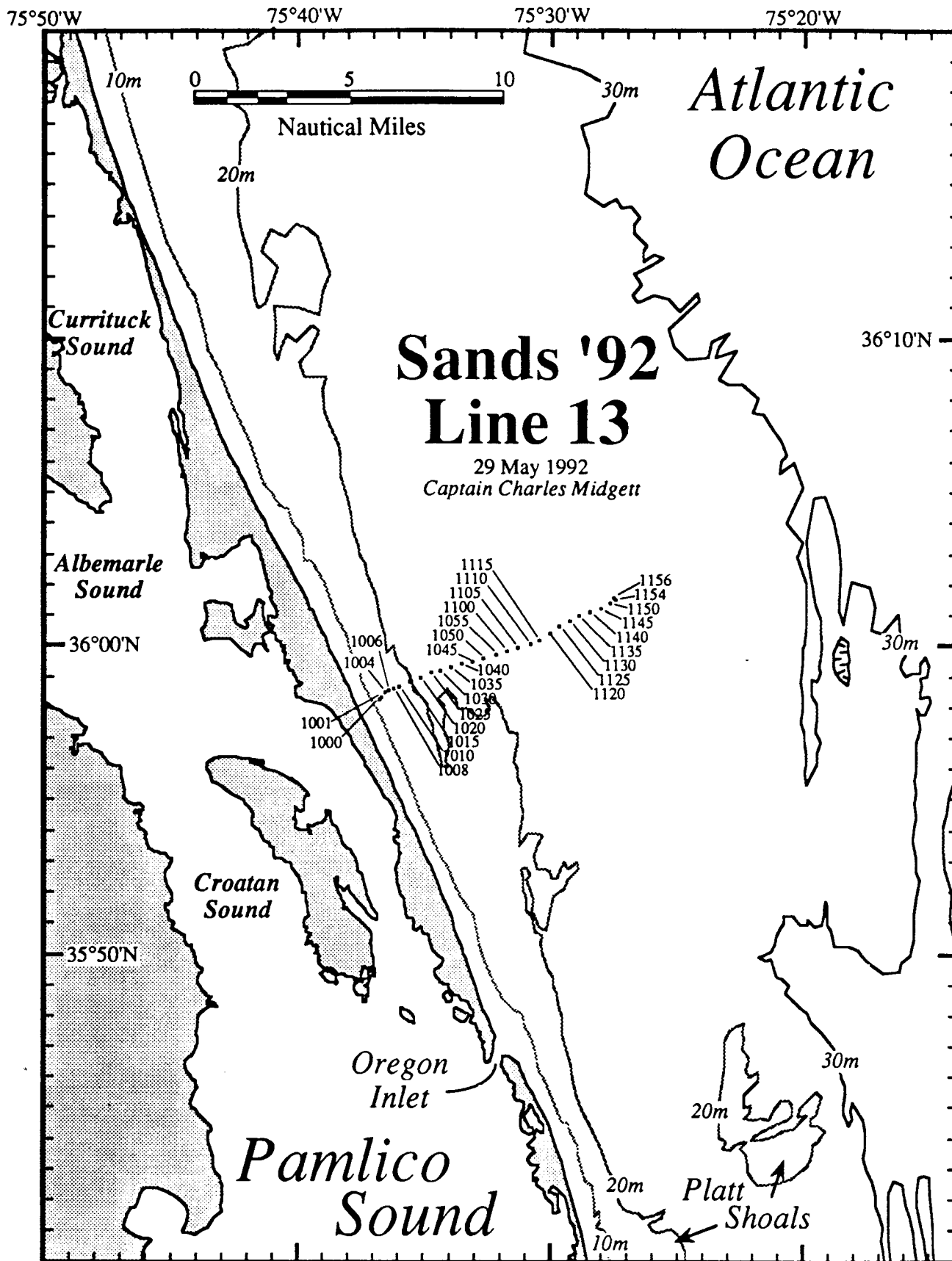
17 September 1992
Captain Charles Midgett



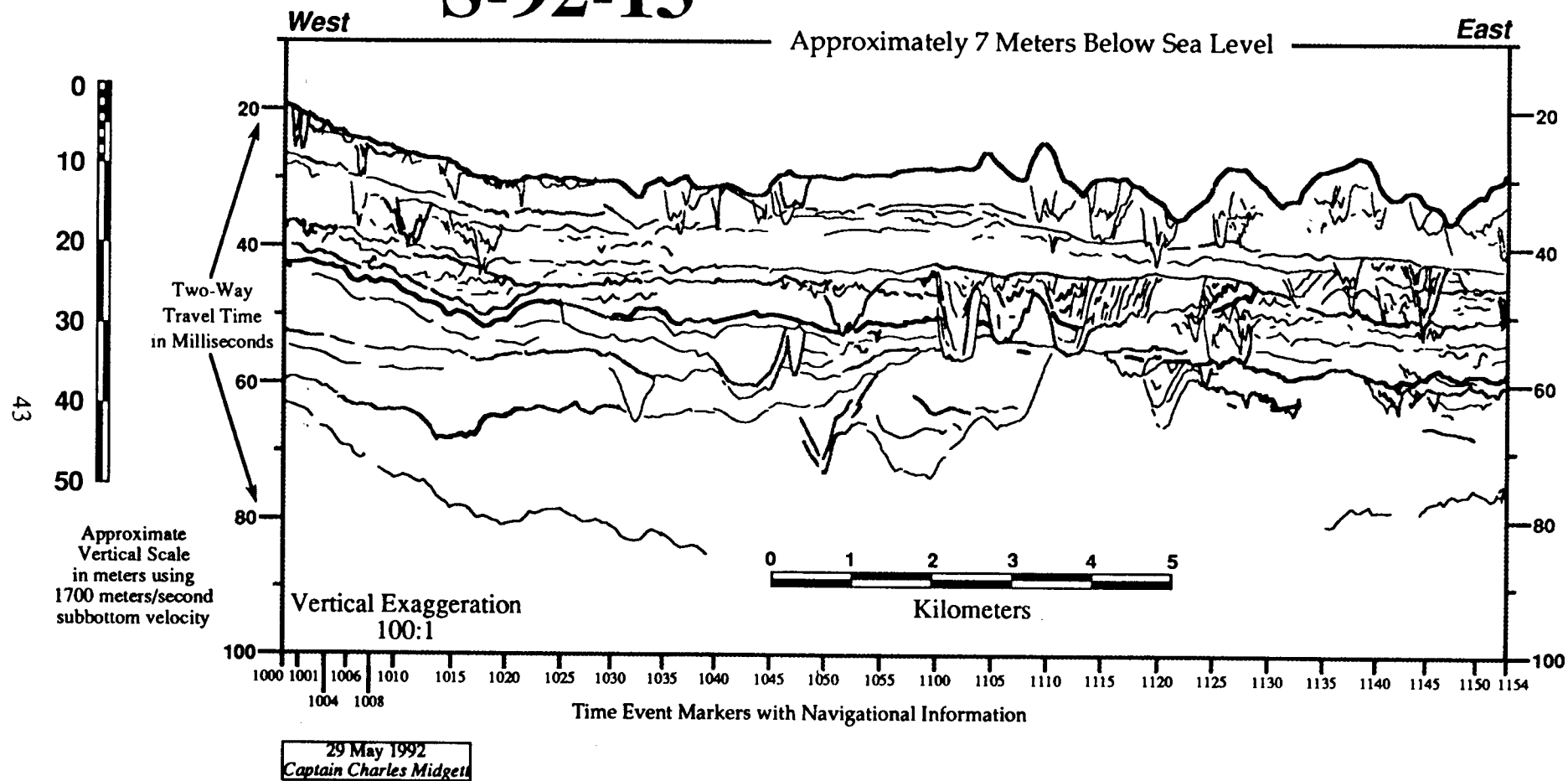
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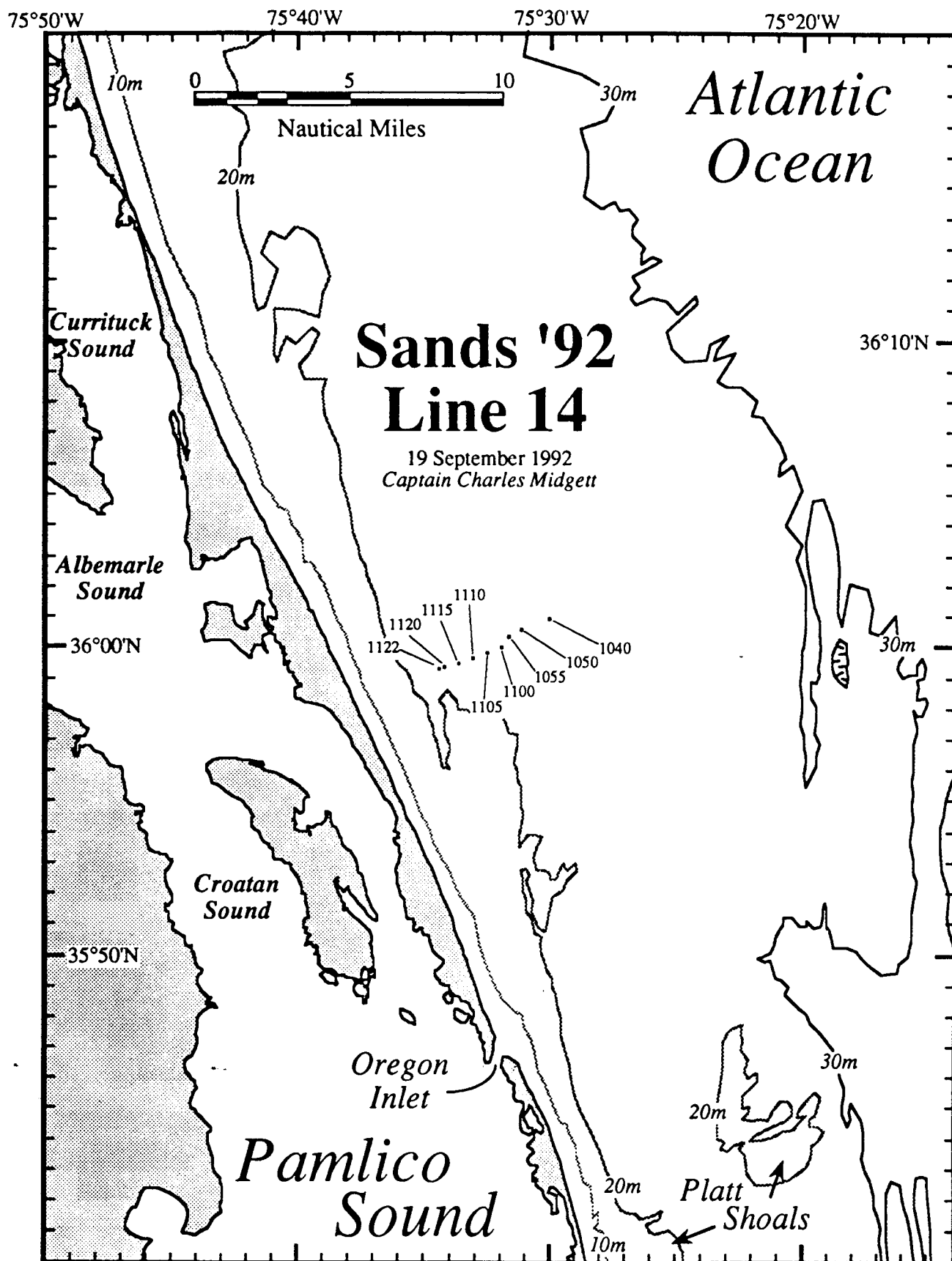


29 May 1992
Captain Charles Midgett

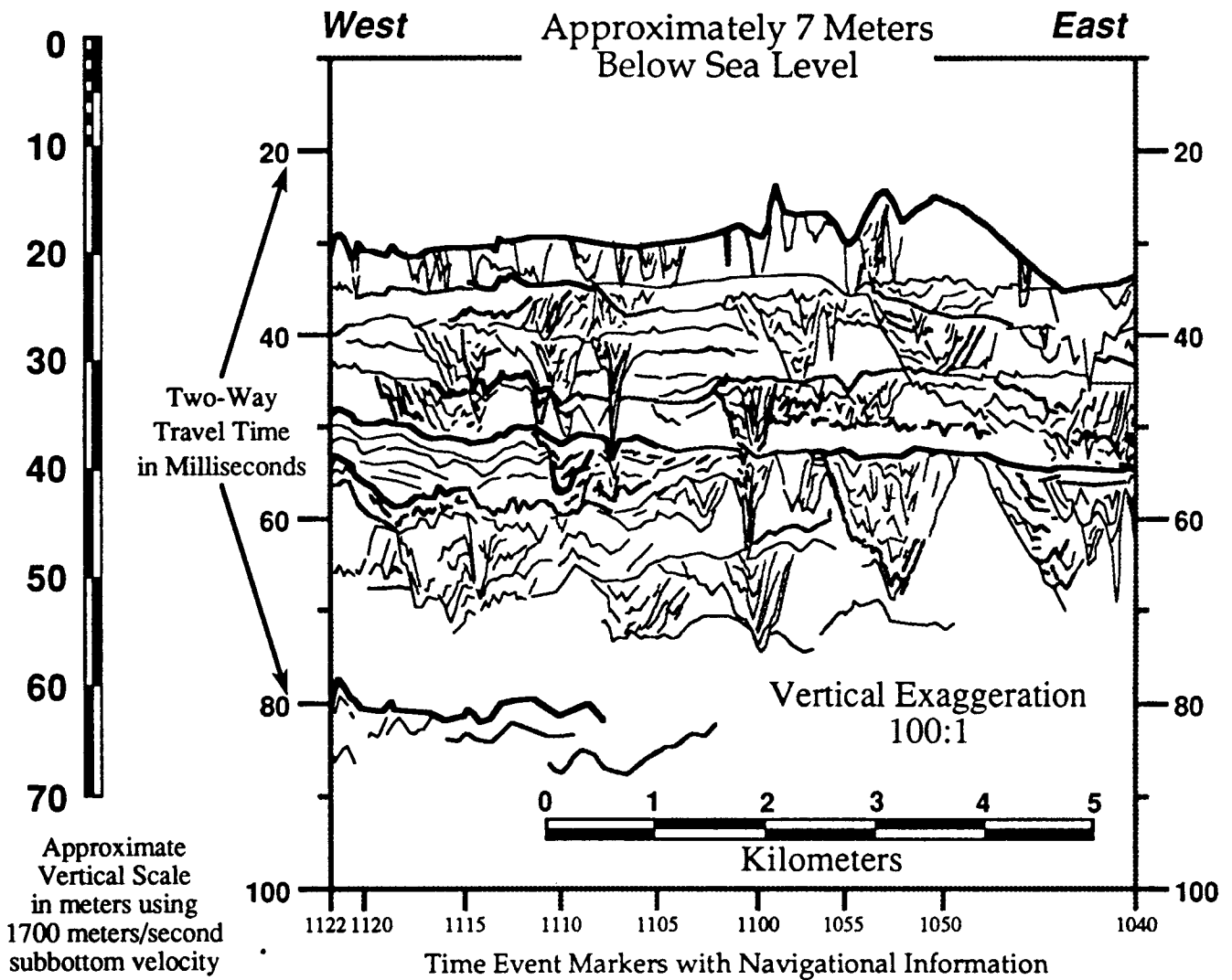


S-92-13

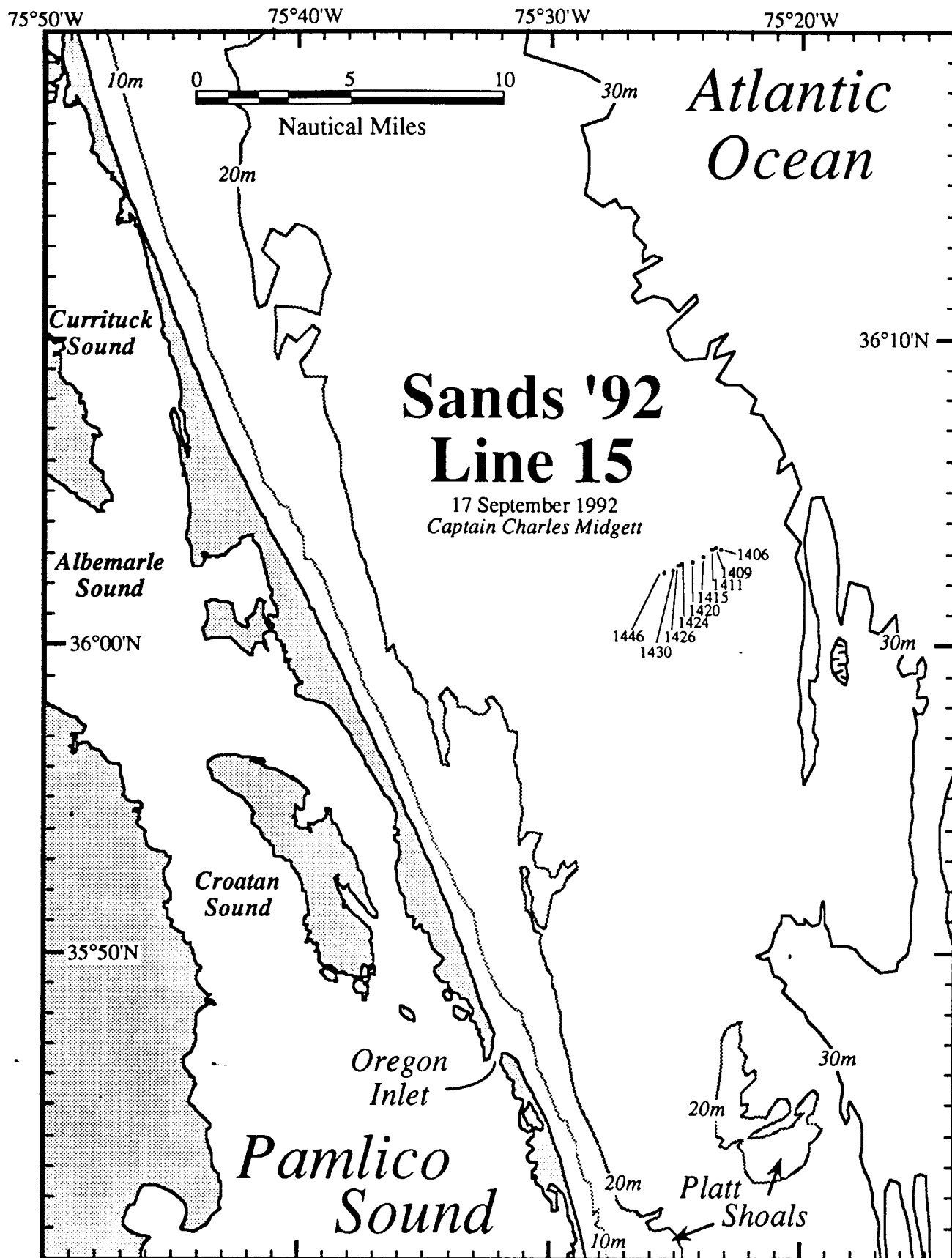




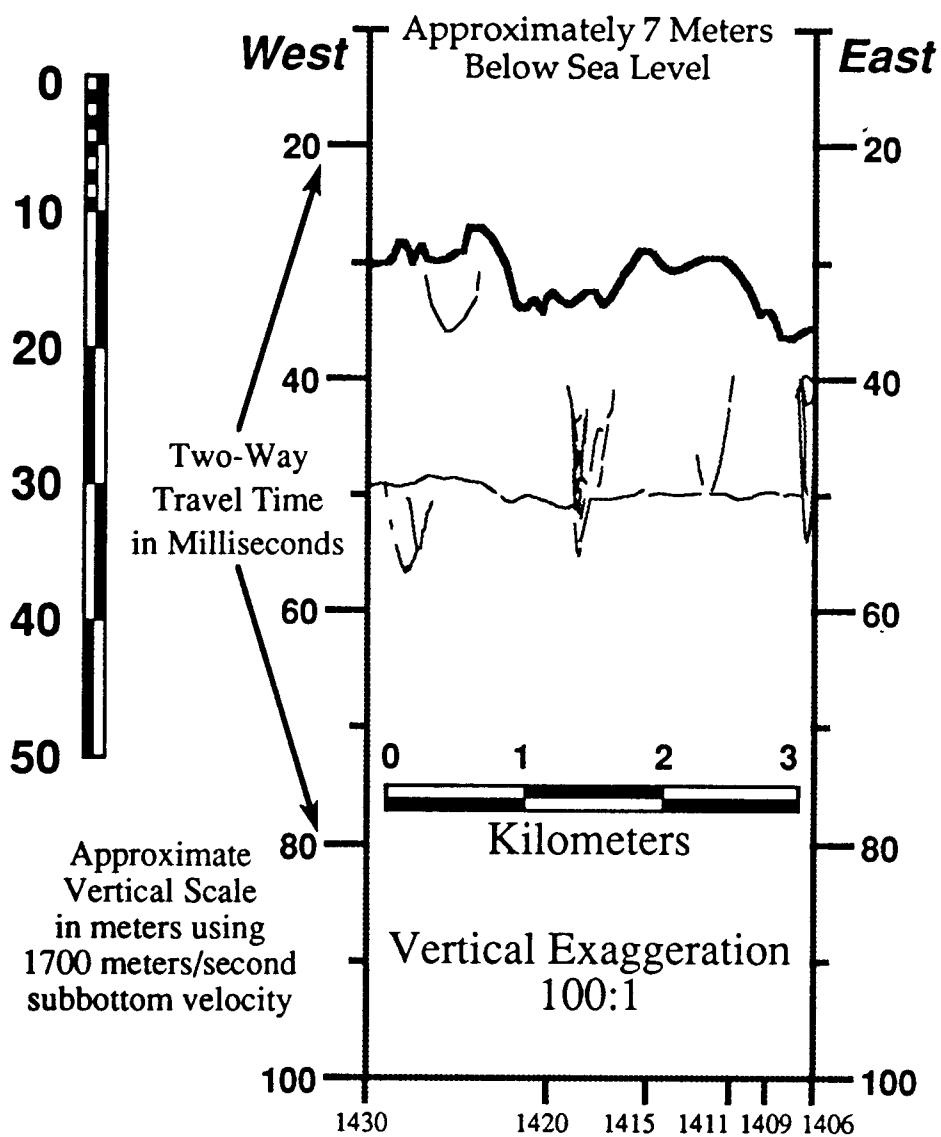
S-92-14



19 September 1992
Captain Charles Midgett



S-92-15



17 September 1992
 Captain Charles Midgett